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SUPPLEMENTARY ENVIRONMENTAL BASELINE STUDIES & EVALUATION OF THE ST. MARY'S RIVER 1980

Great Lakes-St. Lawrence Seaway Navigation Season Extension Program

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The purpose of this study was to expand the existing biological, physical and chemical data for the Middle Neebish Channel in the St. Marys River to help determine environmental effects of suspension and re-distribution of sediments resulting from proposed winter navigation-related activities (i.e., dredging, icebreaking, ship movements). Field data gathered in 1980 supplements data taken in 1979. It considered the biological importance of shallow, littoral areas and the understanding of natural annual variations in the system. It also reviewed fish distribution during winter.

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SUPPLEMENTARY ENVIRONMENTAL BASELINE STUDIES AND EVALUATION OF THE ST. MARYS RIVER DURING 1980

by

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PREFACE

The purpose of this study is to expand existing biological and physical/chemical data for the Middle Neebish Channel in the St. Marys River to help determine environmental effects of suspension and re-distribution of sediments resulting from proposed winter navigation-related activities (i.e. dredging, ice breaking, ship movements). Field data were gathered during February through November 1980 to supplement data taken in 1979.

This report is organized by sub-project dealing with benthic macroinvertebrates, aquatic macrophytes and associated biota, larval fish, juvenile and adult fish, and, physical and chemical aspects of water. Though all sub-projects are closely related, each may be examined independently through this format. References from all sub-projects are combined together at the end of this report.

Potential effects of winter navigation activities are of special concern in narrow channel areas of connecting waters of the Great Lakes. Channel areas adjacent Neebish Island on the St. Marys River may be subjected to alteration if winter navigation programs are enacted. An understanding of the biological systems within these waters is necessary before valid impact assessments can be made. The present study adds new data to information gathered previously, reveals the biological importance of shallow, littoral areas and increases the understanding of natural annual variations in the system. New insight into fish distribution during winter is provided. It is believed that these studies have generic qualities and could be applicable to other sites along the St. Marys River.

Larger catches of fish in 1980 compared to 1979 may demonstrate natural variability of the St. Marys River thus underscoring the limitations of short-term studies. This supplementary study has recently been further extended and several techniques are being replicated to provide a look at natural variations occurring over three years (1979, 1980, and 1981). Also, new data in 1981 will better describe winter fish distribution across a navigation channel, and will provide comparisons between seasonal data at a control site (non-shipping channel) and a potential impact site (shipping channel). A supplementary report for the 1981 data will be submitted in early 1982. Included will be comparisons of the 1979, 1980 and 1981 data and projections of potential effects of winter navigation.

The address of the Information Transfer Specialist for this study is as follows:

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EXECUTIVE SUMMARY

Proposals to extend the Great Lakes commercial shipping season to include winter months have been considered since the 1960's by the United States Army Corps of Engineers. A limited winter shipping program conducted during the 1970's demonstrated that channels and locks could be kept open even during severe winter conditions. Environmental changes resulting from winter navigation activities are of major concern in the narrow connecting waters of the Great Lakes where significant physical alterations would be needed to keep shipping lanes open. However, quantitative biological baseline information for connecting waters is not plentiful making any predictions of impacts questionable.

Baseline environmental studies were begun in 1979 by the Department of Fisheries and Wildlife, Michigan State University, through contract arrangements with the United States Fish and Wildlife Service and Army Corps of Engineers. These studies were extended during 1980 to provide biological information on shallow and deep water habitats to help determine environmental effects of re-distribution of sediments that could result from proposed winter navigation activities. Objectives were as follows: 1) determine composition and abundance of macroinvertebrates in shallow waters; 2) gather additional data on aquatic macrophyte distribution and species occurrence; 3) provide data on annual variation in fish species composition and relative abundance; 4) determine horizontal distribution of the fish fauna on a seasonal basis; and 5) measure physical and chemical parameters to aid in interpreting biological data. Data presented in this report will be combined with earlier data (1979) and with

data being taken during 1981, and a comprehensive report will be submitted in winter, 1982.

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates were collected by PONAR dredge during June and July from shallow littoral sites of 1.0-1.5 m depth (3.3-4.9') near shipping lanes around Neebish Island. Ten samples each were taken at a site in navigation course 7 and in navigation course 9.

Forty five taxa were identified. Chironomidae (13 genera), Oligochaeta, and Ostracoda together comprised over 90% of the total organisms. Ephemeroptera nymphs were also common at the navigation course 7 sampling site. Other taxa collected included Corixidae (2 genera), Trichoptera (5 genera), Megaloptera (1 genera), Lepidoptera, Ceratopogonidae (1 genera), Collembola, Amphipoda (1 genera), Isopoda (2 genera), Hydracarina, Tardigrada, Coelenterata (1 genera), Turbellaria, Hirudinea, Polychaeta (1 genera), Gastropoda (4 genera) and Pelecypoda (2 genera).

Total invertebrate abundance ranged from 4,119 - 42,973/m^2. Average total abundance was 17,539/m^2 in course 7 and 15,321/m^2 in course 9. Statistically significant differences in densities of major groups were noted between stations. Chironomidae were more abundant at navigation course 9, while Ephemeroptera and Ostracoda were more abundant at course 7.

Shallow water may support a benthic fauna similar to that in deeper offshore water, except for the Ostracods. Ostracods are much more abundant nearshore.

MACROPHYTES AND ASSOCIATED BIOTA

The outer and inner depth boundaries of the dominant submersed macrophyte, *Nitella flexilis*, were determined on substrates running east of the navigation channels in Lake Nicolet and Lake Munuscong of the St. Marys River. The outer depth boundary was 6.1 - 8.8 m (20.0 - 28.9') in Lake Nicolet and 4.8 - 5.9 m (15.7 - 19.4') for Lake Munuscong. The inner depth boundary was 2.8 - 2.9 m (9.2 - 9.5') in Lake Nicolet and 2.1 - 2.3 m (6.9 - 7.5') for Lake Munuscong.

The density and distribution of submersed macrophytes were determined along two transects running perpendicular and eastward from the navigation channel in Lake Nicolet. Sample quadrats were used and the percent cover or numbers of stems within these areas were determined. Near the channel *Nitella flexilis* covered approximately 50% of the silty clay substrate. Plant height was 20 - 30 cm (8 - 12"). Shoreward, *Chara globularis* became interspersed with *Nitella* at about 3.3 - 3.5 m (10.8 - 11.5') depth. Also, the quillwort *Isoetes* was interspersed with *Nitella* along one transect, covering approximately 50% of the substrate along a line 200 m (656') shoreward from the 3.5 m (11.5') depth zone. Shoreward to about the 2.5 m (8.2') depth, patches of *Charophytes* were interspersed with *Potamogeton richardsonii*. Densities of *P. richardsonii* ranged from 64 - 256 stems per m^2. At depths shallower than 2.5 m (8.2'), the substrate was mainly sand with few submersed plants. Nineteen additional species of submersed macrophytes were identified in 1980.

Densities of filter feeding animals (clams and sponges) associated with selected submersed plant beds were determined in Lake Nicolet and Lake Munuscong. Algal cell densities in water directly above the filter

feeders were also determined. Within 116 quadrants in Lake Munuscong, only 3 clams were found. Algae collections were dominated by diatoms and averaged 642 cells/ml. In Lake Nicolet, sponge densities ranged from 256 - 640 organisms/m^2. Individual lengths ranged from 1 - 9 cm (.5 - 3.5"). Algae was again dominated by diatoms and ranged from 478 - 717 cells/ml.

ICHTHYOPLANKTON

Fish larvae of 8 taxa were present in 1.0 m net collections at stations 7 and 9 in the Middle Neebish Channel of the St. Marys River from mid July through early September, 1980. Larvae of 11 taxa were collected in 0.5 and 1.0 m push net collections along the edge of the emergent macrophytes. Rainbow smelt was the most abundant taxa in both areas, accounting for 66% of the catch in the channel, and 27% of the catch near the weed beds. Similarly in 1979, rainbow smelt accounted for 64% of all larvae collected in the channel.

Sampling for whitefish and cisco larvae was conducted during 13 April to 4 May, 1980, in shallow littoral areas of Lake Nicolet. A new sampling device (pull net) was constructed by modifying a metal snow scoop and attaching a 363μ mesh plankton net. A total of 17 cisco and 72 lake whitefish larvae were collected in 59 samples. Lake whitefish larvae occurred in 40% of the samples. Highest densities for single samples occurred on 18 April (302 larvae/100 m^3) and on 27 April (250/100 m^3). Cisco larvae occurred in only 10.2% of the samples. Highest densities were on 25 April (193 larvae/100 m^3) and 17 April (182/100 m^3).

The majority of the larvae (85%) collected during July through early September, 1980, were taken near the macrophyte beds. Species composition

and temporal occurrence of larvae in the channel and littoral areas in 1980 was similar to 1979 and to other northern temperate systems. The initiation of sampling in July precluded capture of larvae of winter and early spring spawners.

The importance of the shallow littoral areas, and their associated vegetation, as nursery areas for fish in the St. Marys River is emphasized by the presence of large numbers of larvae. The littoral zone is important as a nursery area, even before regrowth and peak production of the aquatic macrophytes.

JUVENILE AND ADULT FISH

Juvenile and adult fish were sampled in nearshore and offshore habitats at stations in navigation courses 5, 7, 9, and 10 of the St. Marys River. Sampling was concentrated in courses 7 and 9, where dredging activities are proposed. Field work was conducted during February and March, then again during June through November, 1980. A total of 6020 fish representing 44 species were collected with gill nets (72 samples), bottom trawls (16 samples), trap nets (16 samples), and shoreline seines (5 samples). Each collection was examined for total number and total weight of each species. Total length (mm), weight (g) and sex were also determined on a subsample of individuals from each species. Food habits of mature and immature cisco, yellow perch, northern pike, and walleye were determined for both winter and open-water periods.

Bottom Gill Nets

Bottom gill nets were the principal sampling gears. During winter, 40 gill net sets (20 nearshore, 20 offshore) collected 140 fish (catch per effort = 3.5 fish) of 11 species. Gill nets were set for 24 hours.

Cisco comprised 40% of the catch. Other important species included northern pike (14.3%), white sucker (14.3%), yellow perch (10.7%) and walleye (9.3%). Considering all species and sampling areas, nearshore winter catches comprised 55% while offshore catches comprised 45% of the total number of fish. Cisco and white sucker were distributed evenly between shallow and deep zones, yellow perch and northern pike favored shallow water, and walleye preferred deep water. These trends were not always consistent between navigation courses, however.

During summer, 14 gill net sets (12 hour sets) collected 492 fish (catch per effort = 35.1 fish) of 19 species. White sucker comprised 25.2% of the catch. Other important species included cisco (18.9%), yellow perch (16.1%), northern pike (6.9%), rock bass (5.3%), alewife (5.3%), walleye (4.3%), spottail shiner (4.2%), and brown bullhead (4.1%). Nearshore summer catches comprised 61.8% while offshore catches comprised 38.2% of the total number of fish. Of the nine major species, six preferred nearshore water. Northern pike were concentrated offshore, while yellow perch and brown bullhead were more evenly distributed among depth zones. These trends were not always consistent, however, when navigation courses were examined separately.

During fall, 18 gill net sets (12 hour sets) collected 356 fish (catch per effort = 19.8 fish) of 16 species. Cisco comprised 33.4% of the catch. Other important species included white sucker (20.5%), rock bass (14.3%), yellow perch (11.5%) and northern pike (10.7%). Nearshore fall catches comprised 48.9% while offshore catches comprised 51.1% of the total number of fish. Cisco and white sucker preferred nearshore water while rock bass and yellow perch were concentrated in

deeper offshore waters. Northern pike did not exhibit a depth preference.

Bottom Trawls

Bottom trawl samples were collected at night in nearshore (1.5 m, or 5' depth) and offshore (3.1 m, or 10' depth) water at sites within navigation courses 7 and 9.

During summer, 2302 fish of 21 species were collected with 8 trawls (catch per effort = 287.8 fish). Trout-perch were most abundant comprising 27.4% of the total catch. Other important species included spottail shiner (18.7%), johnny darter (14.5%), mottled sculpin (9.6%), yellow perch (7.0%), white sucker (6.6%), and mimic shiner (4.8%). Comparisons were made between onshore and offshore data for navigation course 7. Offshore samples contained 58.6%, while nearshore samples contained 41.4% of all fish. Species preferring nearshore water included spottail shiner, yellow perch, mimic shiner, logperch, and emerald shiner. Species preferring offshore water included johnny darter, mottled sculpin, brook stickleback, ninespine stickleback, and northern pike.

During fall, 1170 fish of 18 species were collected with 8 trawls (catch per effort = 146.3 fish). Johnny darter was dominant and comprised 31.6% of the catch. Other major species included mimic shiner (15.6%), rainbow smelt (11.2%), spottail shiner (8.7%), slimy sculpin (7.5%), mottled sculpin (6.7%), and trout-perch (5.6%). Comparisons were made between nearshore and offshore data for navigation course 7. Offshore samples contained 44.2% while nearshore samples contained 55.8% of all fish. Species caught mainly onshore were johnny darter, logperch, blacknose shiner, sand shiner, and walleye. Species associated mainly with deeper offshore water included brook stickleback, ninespine stickleback, northern pike, and mimic shiner.

Trap Nets

Trap net samples were taken nearshore in emergent vegetation and in open water in navigation courses 5, 7, and 9 during August, September and October, 1980. A sample consisted of setting the gear for either the entire light or dark period of a day.

A total of 1251 fish of 26 species were taken with 16 trap net samples (catch per effort = 78.2 fish). Overall, brown bullhead was the most abundant (19.9% of total catch). Other major species included sand shiner (15.5%), bluegill (13.5%), yellow perch (12.3%), white sucker (10.4%) and blacknose shiner (10.5%). However, fish species composition differed between stations. Minnows (Cyprinidae) dominated collections from navigation course 7, while the bluegill comprised over half (54.6%) of fish from trap nets set in navigation course 9. In navigation course 5 (Lake Nicolet), habitats containing heavy cover, medium cover, and little cover (open water, no emergent macrophytes) were compared. Brown bullhead dominated samples from heavy cover, bluegill were dominant in medium cover, and yellow perch were most abundant in open areas.

Day and night comparisons revealed that about two-thirds of the fish were taken at night.

Shoreline Seine

Shoreline seine hauls were made at night during July and October at sites along navigation courses 5, 7, and 9. A total of 309 fish representing 20 species were taken with five seine hauls (catch per effort = 61.8 fish). Spottail shiner comprised 54.8% of all individuals taken in July, while emerald shiner and trout-perch comprised 54.3% and 26.4% of October collections respectively.

PHYSICAL AND CHEMICAL ASPECTS

Physical-chemical aspects of waters in navigation courses 7, 9, and 10 of the Middle Neebish Channel, St. Marys River, were determined at nearshore (0.3 - 2.0 m; 1 - 6.6') and deep (3 - 6 m; 9.8 - 19.7') sites during February to November, 1980, to expand the baseline data at proposed dredging sites. Most measurements were taken in conjunction with biological sampling.

Water temperatures ranged from 0.1 - 1.0 C during February and March. Beginning in mid-April, temperatures were approximately 2.0 C. Maximum temperatures occurred during late July and mid-August, with values as great as 18.8 C (deep water) and 24.5 C (shallow water) recorded. Temperatures had dropped to 2.1 - 3.2 C by late November. Shallow waters warmed more rapidly in spring and cooled earlier in the fall than deeper water.

Turbidity ranged from 1.0 - 13.2 NTU during June through November, though most measurements (71%) were 3.0 NTU or less. Highest turbidities occurred nearshore, and turbidity averaged 3.0 NTU nearshore compared to 2.4 NTU offshore.

Dissolved oxygen ranged from 5.2 ppm to 12.2 ppm during April through October. All values less than 6 ppm were from nearshore waters. Lowest values occurred during night sampling near beds of emergent vegetation.

Alkalinity and pH were determined less frequently than other physical-chemical measurements in 1980. Alkalinity measurements taken on 14 July, 11 September, and 6 October ranged from 46.0 - 78.0 ppm $CaCO_3$. Fifteen pH measurements taken during 14 July through 11 September ranged from 6.9 to 7.6 standard units. No consistent differences between nearshore and offshore values for pH and alkalinity were apparent.

GENERAL

This report was submitted in partial fulfillment of contract number 14-16-0009-013 by the Department of Fisheries and Wildlife, Michigan State University, under the sponsorship of the Office of Biological Services, U.S. Fish and Wildlife Service. Funding was provided by the U.S. Army Corps of Engineers, Detroit District Office.

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PHYSICAL AND CHEMICAL ASPECTS OF WATER

LIST OF ABBREVIATIONS AND SYMBOLS

C	Celsius, degree
cfs	Cubic feet per second
cm	Centimeter
cm^2	Square centimeter
cm/sec.	Centimeter per second
cpe	Catch per unit effort
ft	Foot
g	Gram
h	Hour
hp	Horsepower
km	Kilometer
m	Meter
mi	Mile
m/s	Meter per second
m^2	Square meter
m^3	Cubic meter
ml	Milliliter
mm	Millimeter
mg/kg	Milligrams per kilogram
mg/l	Milligrams per liter
No/m^2	Number per square meter
$No/100\ m^3$	Number per 100 cubic meters
NTU	Nephelometric turbidity unit
P	Probability or level of significance
pH	Logarithm of the reciprocal of the concentration of free hydrogen ions
ppm	Parts per million
sp.	Species
S.U.	Standard unit
TL	Total length
$\bar{x}$	Mean, or average
yd^3	Cubic yards
YOY	Young of the year
10^3	Thousand
10^6	Million
µ	Micron or micrometer (one millionth of a meter)
%	Percent
'	Foot
"	Inches

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INTRODUCTION

The St. Marys River is the only outflow of Lake Superior to the lower Great Lakes and flows about 120.7 km (75 mi) from headwaters in Whitefish Bay, Lake Superior to Lake Huron at Detour, Michigan (Figure 1). From its headwaters to Lake Huron the St. Marys River descends approximately 6.7 m (22'). Most of this fall occurs at the St. Marys Rapids and Soo Locks located between Sault Ste. Marie, Michigan and Ontario. Below the Sault Ste. Marie area, the river is divided into several channels and shallow lakes first by Sugar Island and subsequently by Neebish and St. Joseph Islands (Figure 2).

Since 1960, river discharge has averaged about 2124 m^3/sec (75,000 cfs). A maximum flow of 3596 m^3/sec (127,000 cfs) was recorded in August 1950, and a minimum flow of 1161 m^3/sec (41,000 cfs) occurred in September 1955. In 1921, complete control of river flow was achieved; under present regulation plans, the minimum flow is controlled at about 1557 m^3/sec (55,000 cfs).

The major shipping link between northwestern United States and metropolitan areas in the lower Great Lakes is through the St. Marys River. As part of a recommendation to extend the Great Lakes navigation season to year-round, the U.S. Army Corps of Engineers (U.S.A.C.E.) has proposed dredging of the Middle Neebish Channel, St. Marys River to allow for two-way traffic. The proposed dredging would remove approximately 1,797,000 m^3 (2,350,373 yds^3) of material along a 27.4 km

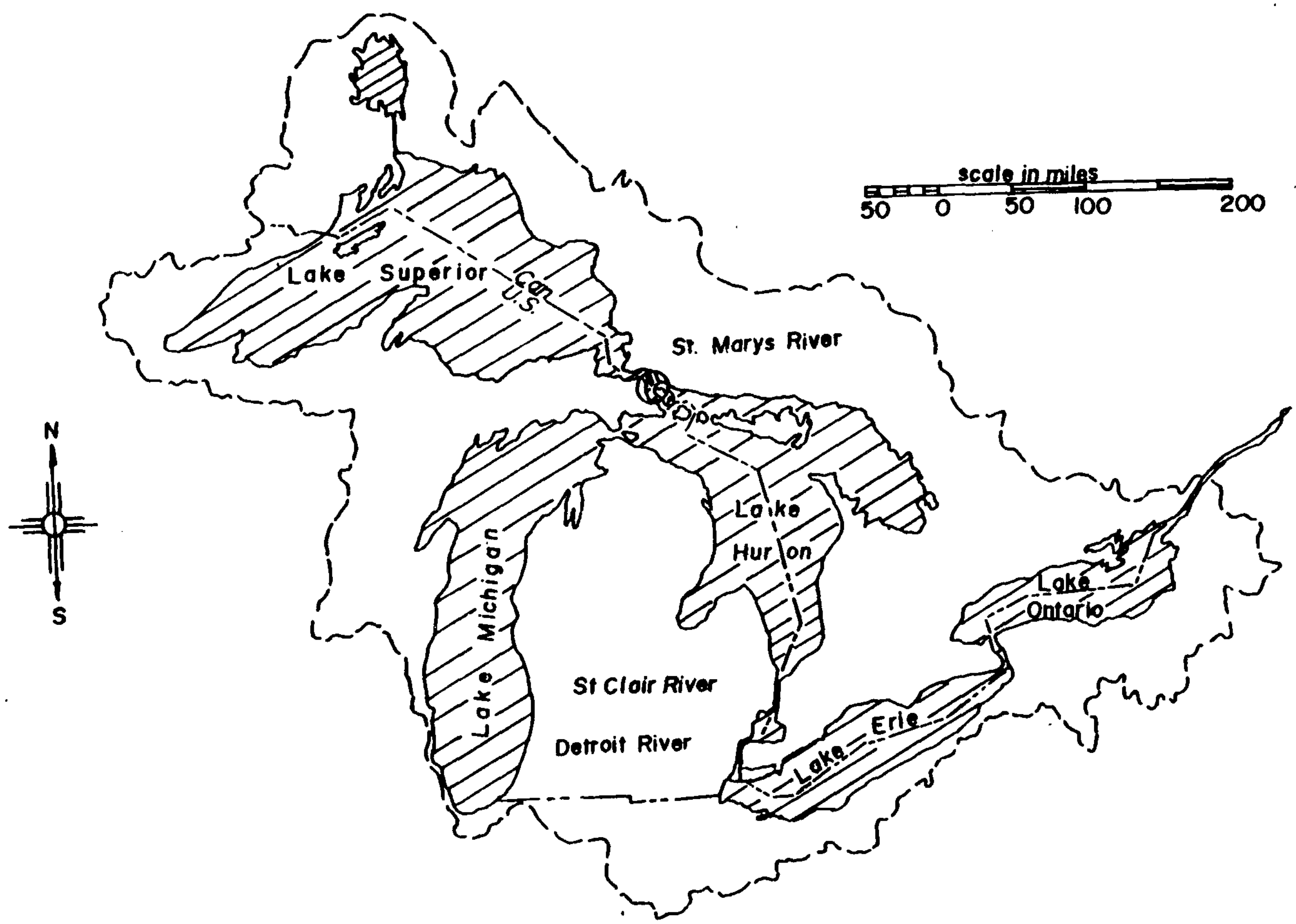

Figure 1. Map of the Great Lakes system showing the general study area on the St. Marys River below Lake Superior.

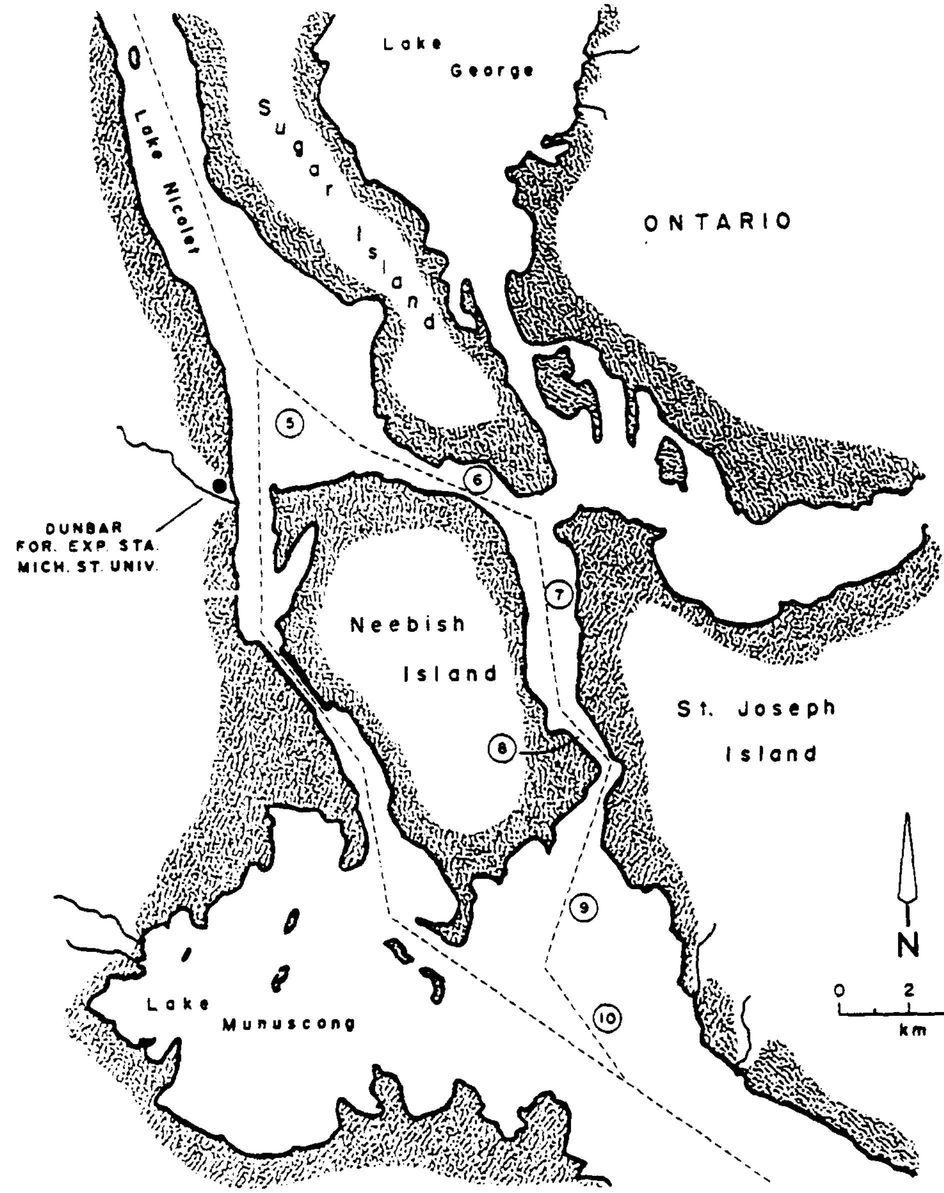

Figure 2. Map of the St. Marys River showing general study sites near Neebish Island, Michigan (navigation courses 5-10).

(17 mi) stretch of the Middle Neebish Channel in navigation courses 5 through 10 (Figure 2) resulting in a 213 m (700') wide channel 8.5 m (28') deep. As presently proposed, the dredged material would be barged down river and disposed of in Lake Huron, about 4 km (2.5 mi) south of Detour Passage. Michigan State University, Department of Fisheries and Wildlife contracted with the U.S. Fish and Wildlife Service in February 1979 to evaluate pre-dredging (baseline) environmental conditions at both the Middle Neebish Channel, St. Marys River, and the proposed dredge spoil disposal site in Lake Huron. Extensive background data on physical/chemical aspects, flora, and fauna were gathered during February through November 1979 and were reported in a recent publication (Liston et al., 1980). The objectives of that study required intensive sampling restricted mainly to near-channel sites in the river where proposed dredging would directly disturb the sediments.

The present study is an extension of the 1979 research with more emphasis on shallow, littoral off-channel environments. In general, this study was contracted to expand the data base for the St. Marys River near Neebish Island to aid in determining environmental effects of re-distribution of sediments that could result from winter navigation-related activities (i.e., dredging, ice breaking, ship movements). Objectives were as follows: 1) determine composition and abundance of macroinvertebrates in shallow waters; 2) gather additional data on aquatic macrophyte distribution and species occurrence; 3) provide data to examine year to year variation in fish species composition and relative abundance; 4) determine horizontal distribution of the fish fauna on a seasonal basis; 5) measure physical and chemical parameters to aid in interpreting biological data.

BENTHIC MACROINVERTEBRATES

METHODS AND MATERIALS

Field

Benthic macroinvertebrate samples were collected from shallow littoral areas of navigation courses 7 and 9 of the Middle Neebish Channel (Figure 1) on 30 June and 9 July, 1980. On each date five samples were collected at the 1.0 - 1.5 m (3.3 - 4.9') contour of each station (10 total samples/station) with a standard PONAR grab which enclosed an area of 484 cm^2 (75 in^2) (Wildlife Supply Co., Saginaw, Michigan).

Samples were rinsed into heavy plastic bags and labeled. Upon returning to the laboratory, samples were preserved in 10% formalin until sorted for organisms.

Laboratory

Samples were rinsed through a standard no. 30 sieve (600 μ aperture) in the laboratory. The resultant slurry was then thoroughly agitated and a subsample of 20% was rinsed through sieves of 250 μ and 149 μ aperture. Organisms retained by the three sieves were then enumerated separately. Organisms were sorted from samples under 10X magnification over a light table. After removing all organisms which could be seen, the glass dish containing the sample was transferred to a black background with illumination from above and checked for opaque organisms. Identifications were accomplished with a sterozoom microscope (10-140X) and a phase contrast compound microscope (100-2000X). Taxonomic references included Bousfield (1958), Heard and Burch (1966), Mason (1973),

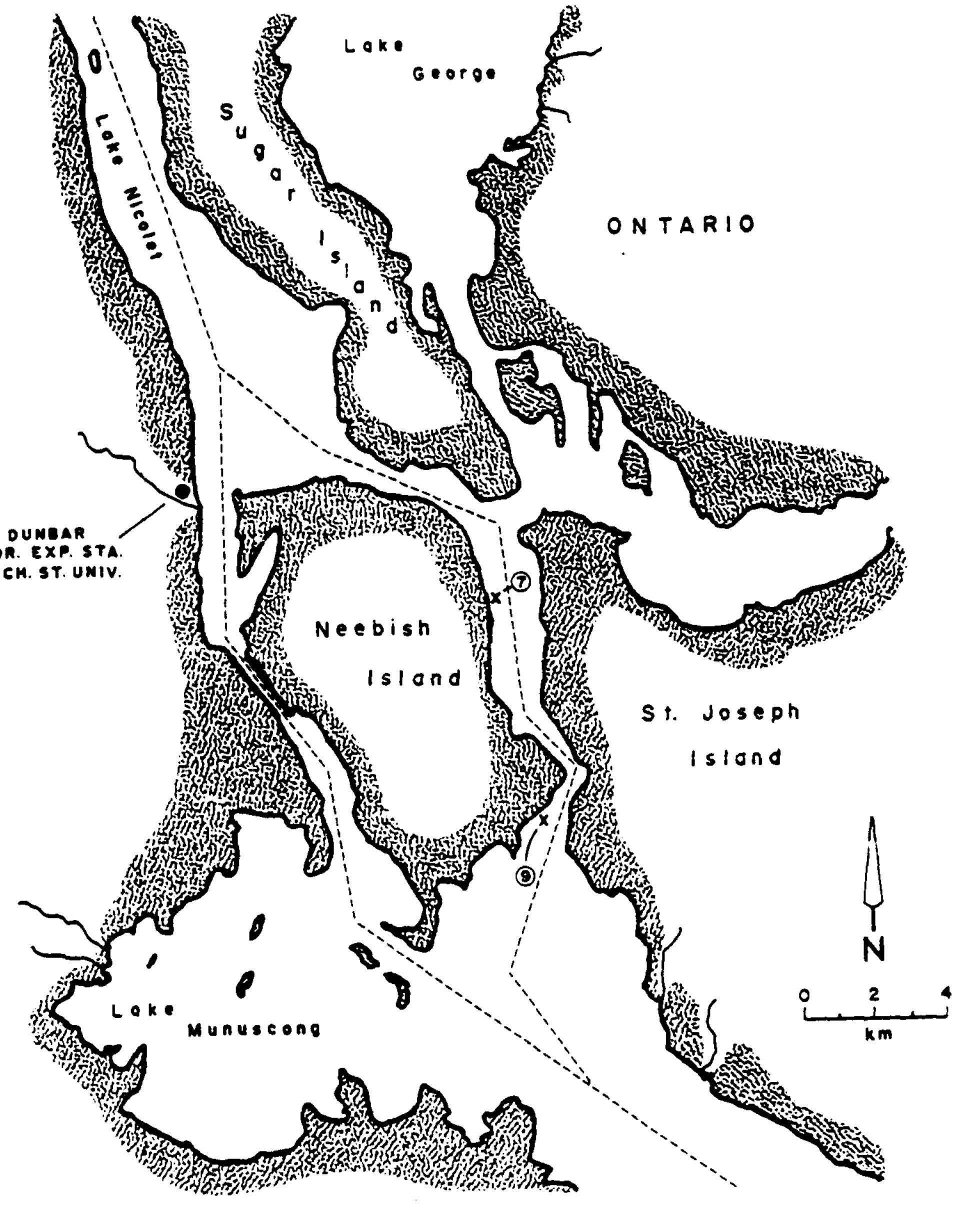

Figure 1. Locations of 1980 benthic macroinvertebrate sampling stations in navigation courses 7 and 9 of the St. Marys River. (Map by Joe Bohr)

Hilsenhoff (1975), Holsinger (1976), Williams (1976), Edmunds et al. (1976), Wiggins (1977) and Pennak (1978).

Statistical Analysis

Abundance data for Chironomidae, Oligochaeta, Ostracoda and Ephemeroptera were subjected to statistical analysis to determine if differences observed among stations were statistically significant. The Mann-Whitney U-Test was applied to data as suggested by Elliott (1977) for comparison of two stations. In all cases a probability level of 5% (P = 0.05) was used.

RESULTS

Taxonomic Composition

Forty-five taxa of benthic macroinvertebrates were identified from 20 PONAR grab samples in the littoral areas of navigation courses 7 and 9 (Table 1). Individually, 40 taxa were identified from course 7 and 35 taxa were identified from course 9. Chironomidae, Oligochaeta and Ostracoda together comprised over 90% of the total organisms. Sediments at the sampling site in course 7 consisted of silt with some clay and occasional charophytes. Sediments at the sampling site in course 9 were predomonantly fine sand.

Navigation Course 7. Samples from course 7 were predominated by Ostracoda (47.5% of total organisms). Oligochaeta and Chironomidae represented 20.9% and 19.0% of the total organisms respectively. Ephemeroptera were also common and represented 5.2% of the total numbers. One genera of Chironomidae (*Pseudochironomus sp.*) comprised 75% of this group at course 7. Nine other genera comprised the remainder of Chironomidae larvae (Table 1). Three genera of Ephemeroptera were collected at course 7. *Ephemera sp.* was most common, followed by *Hexagenia*

Table 1. Mean number of benthic organisms per square meter at navigation courses 7 and 9 at one meter depth. Estimates calculated from ten replicate PONAR grab samples per station.

Taxa	Station 7	Station 9
Ephemeroptera		
Ephemera sp.	621	29
Hexagenia sp.	259	0
Caenis sp.	29	6
Corixidae		
Sigara sp.	2	4
Trichocorixa sp.	0	10
Unidentified Corixidae	8	21
Trichoptera		
Mystacides sp.	23	0
Oecetis sp.	2	6
Polycentropus sp.	19	0
Hydroptila sp.	4	0
Molanna sp.	10	0
Trichoptera pupae	4	0
Megaloptera		
Sialis sp.	4	0
Lepidoptera		
Pyralidae	4	10
Diptera		
Chironomidae		
Pseudochironomus sp.	2,608	0
Cryptochironomus sp.	244	1,161
Stictochironomus sp.	73	0
Paralauterborniella sp.	5	1,493
Polypedilum sp.	0	313
Tribelos sp.	0	32
Tanytarsus sp.	31	1,032
Larsia sp.	36	258
Procladius sp.	11	479
Psectrocladius sp.	109	1,806
Cricotopus sp.	171	793
Diamesa sp.	21	37
Monodiamesa sp.	31	0

Table 1 continued

Taxa	Station 7	Station 9
Chironomidae pupae	97	108
Ceratopogonidae		
Bezzia/Probezzia sp.	389	175
Other Diptera	10	27
Collembola	0	2
Amphipoda		
Hyalella azteca	213	15
Isopoda		
Asellus sp.	2	2
Lirceus sp.	10	0
Hydracarina	2	12
Tardigrada	0	2
Coelenterata		
Hydra sp.	10	2
Turbellaria	8	10
Ostracoda	8,328	1,147
Hirudinea	6	2
Oligochaeta	3,657	6,022
Polychaeta		
Manayunkia sp.	75	0
Gastropoda		
Amnicola sp.	141	2
Lymnaea sp.	13	4
Valvata sp.	13	0
Physa sp.	2	6

Table 1 continued

Taxa	Station 7	Station 9
Pelecypoda		
Sphaerium sp.	166	108
Pisidium sp.	60	72
Unidentified Pelecypoda	8	0
* Total organisms	17,539	15,321

* Nematoda present, but too numerous to quantify.

sp. nymphs. *Caenis sp.* was the third genera, but represented only 0.5% of the total organisms. Five genera of Trichoptera larvae were collected but these combined genera represented less than 1.0% of the total organisms.

Navigation Course 9. Chironomidae larvae were clearly the most abundant organism at course 9 representing 49.1% of the total. Oligochaeta and Ostracoda represented 39.3% and 7.5% of the total organisms respectively. Five genera of Chironomidae larvae (*Cricotopus sp.*, *Psectrocladius sp.*, *Paralauterborniella sp.*, *Cryptochironomus sp.*, and *Pseudochironomus sp.*) combined to make up more than 80% of the Chironomidae. An additional five genera of Chironomidae were identified.

Other organisms collected in low densities (1.0 - 2.2%) at course 9 included Ceratopogonidae, Amphipoda, Pelecypoda and Gastropoda.

Abundance

Estimates of total benthic macroinvertebrate abundance in the two littoral areas ranged from 4,119 - 42,973/m^2. Average total abundance was 17,539/m^2 in course 7 and 15,321/m^2 in course 9.

Abundances of the four most common taxa (Chironomidae, Oligochaeta, Ostracoda and Ephemeroptera) were analyzed statistically to determine if significant differences between stations existed. Comparisons using the Mann-Whitney U-test indicated that Chironomidae larvae abundance at course 9 was significantly greater than at course 7, while abundances of both Ephemeroptera and Ostracoda were significantly greater at course 7 than course 9 ($P < 0.05$) (Table 2). Differences in abundance of Oligochaeta were not significant ($P < 0.05$).

Table 2. Mann-Whitney U-statistic values from comparison of four most common invertebrate taxa among navigation courses 7 and 9. NS=not significant, S=significant at the 0.05 level.

	Mann - Whitney U-statistic		
Taxa	Tabulated Value*	Calculated Value	
Chironomidae	23.0	20.0	S
Oligochaeta	23.0	25.0	NS
Ostracoda	23.0	19.5	S
Ephemeroptera	23.0	0.0	S

* From table 14, p. 114 in Elliott (1977).

DISCUSSION

Forty-five taxa of benthic macroinvertebrates were identified from 20 PONAR grab samples in shallow littoral areas off the Middle Neebish Channel, St. Marys River. Overall, Chironomidae Larvae (33.0%), Oligochaeta (29.5%) and Ostracoda (28.8%) were the most abundant. However, differences in composition and abundance were noted among sampling sites in course 7 and course 9. Chironomidae larvae comprised almost half (49.1%) of the benthic fauna at course 9, while Oligochaeta (39.3%) and Ostracoda(7.5%) made up most of the remainder of organisms. At course 7 Chironomidae larvae comprised only 19.0% of the benthic organisms while Ostracoda comprised 47.5% of the total. Oligochaeta comprised 20.9% of the total organisms at course 7 while Ephemeroptera nymphs were also common.

Previous investigators studying the St. Marys River have reported an abundance of Oligochaeta and Chironomidae (Liston et al., 1980; Hiltunen,1978; Poe et al., 1979). Gastropoda also comprised a large portion of samples from upper Lake Nicolet in several previous studies (Gleason et al., 1979; Poe et al., 1979). None of the previous authors report large numbers of ostracods. However, two of these studies (Gleason et al., 1979; Poe et al., 1979) were conducted under ice. It is likely that the number of ostracods found in this study more accurately reflects actual densities in the littoral region of the St. Marys River during summer and is not the result of differing sampling methods by different investigators. Samples collected during 1980 were handled in the same manner as samples collected during 1979 in deeper water (Liston et al., 1980). The largest number of species of Ostracoda have been reported to occur in water of 1 m or less, with little current

and in association with aquatic vegetation (Pennak, 1978). However, Delorme (1978) reported low densities of ostracods occurring in the deeper portions of Lake Erie.

Information on the Ostracoda is sparse because of taxonomic problems. Pennak (1978) implied that Ostracoda can withstand a wide range of environmental conditions. However, Delorme (1978) suggested low dissolved oxygen levels in Lake Erie have eradicated some species and limited the distribution of others.

The overall mean density of total benthic organisms from 20 PONAR grab samples was $16,430/m^2$. Densities at both sampling sites were similar and in the range of densities reported for shallow depths by Gleason et al. (1979) and Poe et al. (1979). Significant differences in the density of Chironomidae larvae, Ostracoda and Ephemeroptera were found among stations. Oligochaeta densities were not significantly different among sites. Chironomidae larvae were more abundant at course 9, while Ostracoda and Ephemeroptera nymphs were more abundant at course 7. These differences are likely the result of differences in sediment type. Sediments at course 9 were primarily fine sand while sediments at course 7 were mainly silt and clay. Dermott (1978) reported Orthocladinae (Chironomidae) were positively associated with sandy sediments in Lake Superior. Duffy and Liston (1978) also reported highest densities of chironomids in Lake Michigan from stations with sandy substrate. The finer silt and clay particles at course 7 are more suitable material for burrow building and feeding by Ephemeridae, the principle Ephemeroptera collected.

Excepting greater numbers of ostracods, the shallow areas support a benthic fauna similar to the fauna of deeper waters. Due to similarities in the nearshore and offshore communities, the nearshore benthic community should respond to excessive silt in a manner similar to the offshore community as reviewed by Liston et al. (1980). That is, filter feeding organisms such as burrowing mayflies (*Hexagenia* sp. and *Ephemera* sp.) or clams (Pelecypoda) may be expected to experience mortality. Also see reviews by Peddicord and McFarland (1978), Stern and Stickle (1978) and Morton (1977) on the effects of siltation in aquatic environments.

SUMMARY

Benthic macroinvertebrates were collected during June and July from shallow zones (1.0-1.5 m; 3.3-4.9' depths) in navigation courses 7 and 9 of the St. Marys River to provide baseline data on taxonomic composition and abundance. Collections supplemented earlier (1979) data taken in deeper waters near shipping channels. Ten PONAR grab samples were collected from each course. Samples were washed through seives having mesh sizes of 600μ, 250μ, and 149μ prior to sorting and identification.

A total of 45 taxa were identified, though Chironomidae larvae (13 genera), Oligochaeta, and Ostracoda were dominant and comprised 33.0%, 29.5%, and 28.8% respectively of the total numbers of organisms from all samples. Ephemeroptera nymphs (3 genera) were common in some samples (especially course 7), and comprised 2.9% of the total number. Other taxa included Corixidae (2 genera), Trichoptera (5 genera), Megaloptera (1 genus), Lepidoptera, Ceratopogonidae (1 genus), Collembola, Amphipoda (1 genus), Isopoda (2 genera), Hydracarina, Tardigrada, Coelenterata (1 genus), Turbellaria, Hirudinea, Polychaeta (1 genus), Gastropoda (4 genera), and Pelecypoda (2 genera).

Abundance estimates for individual samples ranged from 4,110 - 42,973 organisms per m^2. The mean density from all 20 samples was 16,430 organisms per m^2, which was similar to shallow water densities reported from other studies on the St. Marys River.

Shallow areas appear to support a benthic fauna similar to that in deeper offshore water, except for the Ostracods. Ostracods are much more abundant nearshore.

MACROPHYTES AND ASSOCIATED BIOTA

METHODS AND MATERIALS

Macrophytes

During the 1979 study, charophytes were the dominant submersed plant in the Neebish Island region of the St. Marys River (Liston et al., 1980). The boundaries for these plants were not well established during 1979, particularly along the eastern inshore area of the channels in both Lake Nicolet and Lake Munuscong. Therefore, it was important to delineate these boundaries for distribution mapping and biomass estimates.

Nitella flexilis was the only macrophyte growing in the deeper water of the starboard (right) side of the upbound channel in 1979. It was thought to stop abruptly in a wall of vegetation at its outer depth limit. Stross (1979) has shown this sort of distribution pattern in Lake George, New York, to be controlled by the quality of light in the water. It was important to establish for a baseline the outer depth limit of this plant in Lake Nicolet and Lake Munuscong. Increases of suspended sediments in the St. Marys River could alter the outer depth limit for this plant by limiting light penetration.

The outer boundary was determined by sampling from a boat using a conventional PONAR dredge with metered line. The inner boundaries were determined by swimming with snorkel and scuba.

In addition to determining depth boundaries for the charophytes, distribution of aquatic plants and their densities were recorded for

two transects that ran perpendicular to the upbound channel in Lake Nicolet (Transects 1 and 2, Figure 1). Metal rules were used to form sample quadrats within the beds of vegetation. The percent cover or number of stems within these areas were determined. Notes were made of plant growth form and sediment type. Transect 1 was approximately 1.3 km long while transect 2 had a length of 1.4 km.

During the interval of August 25 - September 12, 1980, aquatic macrophytes were collected in the field for identification to extend the species list. Only those plants that were not previously described were taken. They were identified in the laboratory at the Dunbar Field Station. Microscopic examination was made on all charophyte and quillwort samples. Fassett (1957), Voss (1972), and Wood (1967) were used for taxonomic naming of the species. The site lcoations were determined from NOAA Chart No. 14883.

Filter Feeding Macroinvertebrates and Algae Associated With Macrophytes

During the 1979 study, large populations of two major types of non-selective filter-feeding macroinvertebrates were observed: sponges on the littoral plane north of Neebish Island and clams in the charophyte meadows of eastern Lake Munuscong. The objective during 1980 was to estimate the density of those organisms and analyze the phytoplankton in the water they were filtering.

The density of clams was determined for Corridor II (Figure 1) by swimming. Divers, using SCUBA, would randomly disperse a metal grid (0.0625 m^2) onto the sediment surface and then collect by hand all clams over 3 cm (1") in length within that area. Water for the phytoplankton analysis was collected by a diver swimming down and then filling a one-liter poly-bottle 10 cm (4") above the sediment surface.

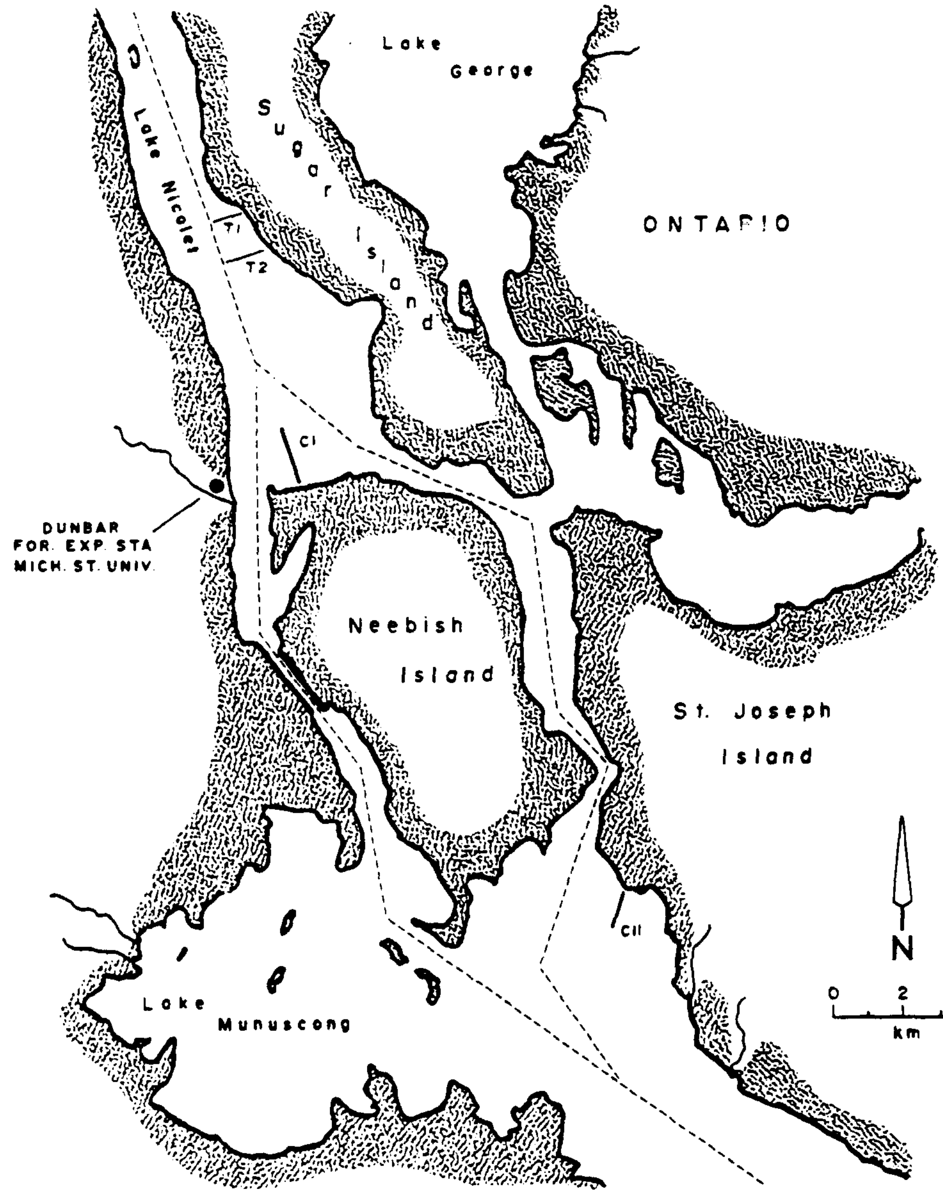

Figure 1. Locations of transects (T1 and T2) where distribution and density of submerged aquatic plants were recorded and corridors (CI and CII) where densities of filter-feeding invertebrates were determined in the St. Marys River.

The sample was then preserved in the field with 2 ml of I-KI. The density of sponges was estimated along Corridor I (Figure 1) in a similar manner, but instead of collecting all the organisms within the grid, they were counted. Water samples were collected from areas adjacent to the sponges by a diver and preserved as described above. Heard and Burch (1966) and Pennak (1978) were used for the taxonomic naming of the collected specimens of both the clams and sponges.

The preserved water samples were filtered through a 0.45 μ HA Millipore membrane filter. These were air-dried, then cleared for examination with microscopic immersion oil. Twenty random fields of vision were then counted for total number of algal cells under oil immersion (1000X) using an AO Series 10 Phasestar microscope. After the counts for total number, the relative abundance of the phytoplankton from the different sites was determined by scoring, according to genus or species, the first 100 individuals occurring in randomly selected fields at 1000X. These filters were also examined for those rare occurrences of additional species and all algae were named following the taxonomic categorization of Prescott (1961) and Weber (1971).

RESULTS AND DISCUSSION

Macrophytes

The outer boundary (depth) of *Nitella flexilis* along the right edge of the upbound channels in Lake Nicolet varied from 6.1 m to 8.8 m (20 to 29'); in Lake Munuscong it varied from 4.8 m to 5.9 m (15.7 to 19.4') depth. Field observations indicated that large mats of *Nitella flexilis* were moving along the sediment surface and being transported downstream. Disruption of the outer edge of the *Nitella* bed, either

from ship activity or senescence of the plants, might cause displacement of the mats resulting in the highly variable depth limits. The inner boundary of the charophytes was more discrete. In Lake Nicolet this boundary was between 2.8 to 2.9 m (9.2 to 9.5') while in Lake Munuscong the inner edge ranged in depth from 2.1 to 2.3 m (6.9 to 7.5').

The data for the transects on the right side of the upbound channel in Lake Nicolet can be characterized in the following way. For both transects the outer boundary (the area closest to the channel) was populated with the charophyte *Nitella flexilis* at a density of about 50% cover. The sediment type was silty clay and the plants were low growing, 20 to 30 cm (8" to 12") in height. Proceeding shoreward, *Chara globularis* began to be interspersed with the *Nitella* at a water depth of 3.3 to 3.5 m (10.8 to 11.5'). The total plant cover remained at approximately 50% but the percent of *Nitella* and *Chara* constituting that cover would vary from 70% *Nitella* and 30% *Chara* to 75% *Chara* and 25% *Nitella*. On Transect 1 (Figure 1), a bed of *Isoetes riparia* was found beginning at a depth of 3.5 m (11.5') and extending approximately 200 m (656') shoreward. The *Isoetes* covered 50% of the silty-clay sediment surface, was 8 to 10 cm (3 to 4") tall and had formed spores. The only other plant that was found in association with *Isoetes* was an occasional plant of *Nitella flexilis*. On Transect 2 (Figure 1) no *Isoetes* was observed. Shoreward of the *Isoetes* the charophytes dominated the submersed plant community excluding the occasional patches of *Potamogeton richardsonii*. These patches of plants were extremely variable in size, with most being less than 15 m (49') in width. The plants were found to be growing to within 0.25 to 0.33 m (.8 to 1.1') of the water surface, they were in seed, and densities ranged from 64

stems m^{-2} to 256 stems m^{-2}. In the beds of high density there were no other plants, but within the low density areas, *Nitella flexilis* was found as an understory. Between the beds of *Potamogeton richardsonii* the charophytes were essentially the only submersed plants present; occasionaly a few plants of *Potamogeton robbinsii* and *Ranunculus* species were found. This pattern of charophytes interspersed with patches of *Potamogeton richardsonii* continued shoreward until a depth of approximately 2.5 m (8.2') was reached. The shallower reaches between that depth and Sugar Island had sediments that were predominantly sand.

The extension of the macrophyte species list is given in Table 1. It is now believed that the submersed flora is fairly well documented for the Neebish Island region. This is not the case for the semi-aquatic emergents or the woody shrubs. Field work during the time these plants would be in fertile conditions in the future would allow for the continuation of the comprehensive species list.

Filter Feeding Macroinvertebrates and Algae Associated with Macrophytes

Three clams were collected from 116 quadrats taken along Corridor II in Lake Munuscong on 10 September, 1980. Additional clams were collected from the area for identification purposes. The genera of pelecypods from this area were: *Elliptio*, *Strophitus*, and *Lampsilis*. The density of the algae in the water collected from 10 cm (4") above the sediment surface was 642 cells ml^{-1}. The phytoplankton was dominated by the diatoms (91% occurrence) (Table 2).

Reasons for the low abundance of clams along this corridor on this date are not known. Tentative hypotheses for the small numbers observed are: predatory pressure; low point in population cycles; or, migration out of this area and into a more suitable habitat.

Table 1. Additional macrophyte species found in portions of the St. Marys River during August 25, 1980 to September 12, 1980.[1]

Species	Common Name	Location[2]	Remarks
Acorus calamus L.	Sweet-flag	A	Collected by Diane Ashton
Alisma plantago - aquatica L.	Water plantain	A	Collected by Diane Ashton
Batrachospermum sp.	Red alga (Rhodophyta)	A	Epiphytic on decaying stems of *Scirpus*
Carex retrorsa Schw.	Carex	B	
Chara braunii Gm.	Stonewort	A	In 0.5 m of water; silty clay
Chara vulgaris L.	Stonewort	A	In 0.5 m of water; silty clay
Dulichium arundinaceum (L.) Britton	Three-way sedge	B	
Isoetes braunii Dur.	Quillwort	A	Most morphologically similar to *I. riparia* but one plant had leaves 20 cm long; found in 0.45 m of water.
Najas flexilis (Wild.) Rostk. & Schmidt	Bushy pondweed	A, B	
Nitella macounii (T.F.A.) T.F.A.	A charophyte	A	

1 See Liston et al. 1980 for previous species list.

2 A - north of the mouth of the Charlotte River (within 500 m); B - north shore of Shingle Bay (Lake Nicolet); C - eastern shore of Neebish Island near Chicken Islands.

Table 1. continued.

Species	Common Name	Location[2]	Remarks
Nuphar variegatum Engelm.	Yellow water lilly	A	
Potamogeton crispus L.	Curly-leaf pondweed	C	
Potamogeton natans L.	Floating brownleaf; Floating-leaf pondweed	A	
Potamogeton pectinatus L.	Sago pondweed	A	
Potamogeton spirillus Tuckerman	Pondweed	A, B	Growing in dense clusters in 0.5 m of water.
Ranunculus flabellaris Raf.	Yellow water crowfoot	A	
Sagittaria latifolia Willd.	Wapato; Duck-potato	A	
Salix longifolia Muhl.	Willow	B	
Scirpus validus Vahl.	Softstem bulrush; Great bulrush	B, C	Interspersed with *Scirpus acutus*.

Table 2. The percent occurrence and listing of algal species present in the water from a sample collected on September 10, 1980 from the area designated "c" on Corridor II (cf. Figure 1, Liston et al., 1980).

Algae [1]	Percent Occurrence
Chrysophyta	
Bacillariophyceae	
Asterionella formosa	-
Cocconeis sp.	3
Cyclotella sp. *(C. Meneghiniana)*	24
Cymbella sp.	1
Fragillaria crotonensis	5
Gomphonema sp. *(G. acuminatum)*	13
Navicula sp.	21
Nitzschia sp.	11
Pinnularia sp.	7
Synedra sp.	3
Unidentifiable pennales	3
Chrysophyceae	
Chrysosphaerella longispina	-
Dinobryon cylindricum	5
Chlorophyta	
Scenedesmus quadricauda	4

[1] The percent occurrence for the algae listed by a generic name and then followed by a species parenthetically is for the genera since there were more than one species but they could not be differentiated during the counting procedure.

The sponges along Corridor I of Lake Nicolet ranged in density from 256 organisms m^{-2} to 640 organisms m^{-2} on 10 September, 1980. They varied in size from 1 to 9 cm (.5 to 3.5") in length and were identified as *Spongilla lacustris* (L.). A noticable green coloration was the result of the inter- and intracellular "zoochlorellae" which in this case was identified as the green alga *Chlorella*. The density of the algae in the water sampled near the sponges at site "a" and "b" on Corridor I was 478 ml^{-1} and 717 cells ml^{-1}, respectively. The algae in both areas was dominated by the diatoms (Tables 3 and 4).

Table 3. The percent occurrence and listing of algal species present in the water from a sample collected on September 5, 1980 from the are designated "a" on Corridor I (cf. Figure 1, Liston et al., 1980).

Algae[1]	Percent Occurrence
Chrysophyta	
Bacillariophyceae	
Asterionella formosa	-
Cocconeis sp. *(C. pediculus)*	6
Cyclotella sp. *(C. meneghiniana)*	41
Cymbella sp. *(C. prostrata)*	4
Fragillaria crotonensis	3
Gomphonema sp. *(G. acuminatum)*	3
Gyrosigma kutzingii	-
Navicula sp.	15
Nitzschia sp.	3
Pinnularia sp.	7
Synedra sp.	-
Unidentifiable pennales	12
Unidentifiable centrales	1
Chrysophyceae	
Chrysosphaerella longispins	4
Dinobryon cylindricum	-
Chlorophyta	
Ankistrodesmus sp.	-
Pediastrum sp.	1
Cyanophyta	
Anabaena	-

[1] The percent occurrence for the algae listed by a generic name and then followed by a species parenthetically is for the genera since there were more than one species but they could not be differentiated during the counting procedure.

Table 4 . The percent occurrence and listing of algal species present in the water from a sample collected on September 5, 1980 from the area designated "b" on Corridor I (cf. Figure 1, Liston et al., 1980).

Algae[1]	Percent Occurrence
Chrysophyta	
Bacillariophyceae	
Asterionella formosa	-
Cocconeis sp.	4
Cyclotella sp. *(C. meneghiniana)*	44
Cymbella sp.	10
Diploneis sp.	1
Fragillaria crotonensis	11
Gomphonema sp. *(G. acuminatum)*	4
Gyrosigma kutzingii	-
Navicula sp.	12
Nitzschia sp.	3
Pinnularia sp.	2
Synedra sp.	-
Unidentifiable pennales	5
Chrysophyceae	
Chrysosphaerella longispina	-
Mallamonas sp.	-
Dinobryon cylindricum	-
Chlorophyta	
Pediastrum sp.	-
Scenedesmus quadricauda	4
Cyanophyta	
Merismopedia sp.	-
Chroococcus sp.	-
Crytophyta	
Cryptomonas ovata	-

[1] The percent occurrence for the algae listed by a generic name and then followed by a species parenthetically is for the genera since there more than one species but they could not be differentiated during the counting procedure.

SUMMARY

The outer and inner depth boundaries of the dominant submersed macrophyte, *Nitella flexilis*, were determined on substrates running east of the navigation channels in Lake Nicolet and Lake Munuscong of the St. Marys River. The outer depth boundary was 6.1-8.8 m (20.0-29.0') in Lake Nicolet and 4.8-5.9 m (15.7-19.4') in Lake Munuscong. The inner depth boundary was 2.8-2.9 m (9.2-9.5') in Lake Nicolet and 2.1-2.3 m (6.9-7.5') for Lake Munuscong.

The density and distribution of submersed macrophytes were determined along two transects running perpendicular and eastward from the navigation channel in Lake Nicolet. Sample quadrats were used and the percent cover or numbers of stems within these areas were determined. *Nitella flexilis* covered approximately 50% of the silty clay substrate near the channel. Plant height was 20-30 cm (8-12"). Shoreward, *Chara globularis* became interspersed with *Nitella* at about 3.3-3.5 m (10.8-11.5') depth. Also, the quillwort *Isoetes* was interspersed with *Nitella* along one transect, covering approximately 50% of the substrate along a line 200 m shoreward from the 3.5 m (11.5') depth zone. Shoreward to about the 2.5 m (8.2') depth, patches of *Charophytes* were interspersed with *Potamogeton richardsonii*. Densities of *P. richardsonii* ranged from 64-256 stems per m^2. At depths shallower than 2.5 m (8.2'), the substrate was mainly sand with few submersed plants.

Nineteen additional species of submersed macrophytes were identified in 1980. The species list for submersed macrophytes appears complete; however, further additions could be made to the list for aquatic emergents or woody shrubs.

Densities of filter feeding animals (clams and sponges) associated with selected submersed plant beds were determined in Lake Nicolet and Lake Munuscong. Algal cell densities in water directly above the filter feeders were also determined. Within 116 quadrants in Lake Munuscong, only 3 clams were found. Algae collections were dominated by diatoms and averaged 642 cells/ml. In Lake Nicolet sponge densities ranged from 256-640 organisms/m^2. Individual lengths ranged from 1-9 cm (.5-3.5"). Algae was again dominated by diatoms and ranged from 478-717 cells/ml.

ICHTHYOPLANKTON

METHODS AND MATERIALS

Field

Middle Neebish Channel. Ichthyoplankton samples were collected at night at Stations 7 and 9 in the Middle Neebish Channel of the St. Marys River from mid-July through mid-September, 1980 (Figure 1, Table 1). Duplicate tows of a bridled 1.0 m nitex conical plankton net (351μ mesh) were made in the channel at each station. A General Oceanic digital flowmeter (Model 2030) was mounted in the mouth of the net to estimate the amount of water filtered. A General Oceanics collection bucket was modified by the addition of a rectangular 351 μ mesh patch to the side of the bucket to facilitate concentration of samples (Duncan, 1978; Graser, 1978).

Each tow was a 5-minute, stepped oblique (bottom to surface) tow, the net being towed for approximately 1½ minutes near the bottom, at mid-depth and the surface. The net was towed off the front of a 16 ft. Boston Whaler while backing into the current. A Wildco line/cable Clinometer was used to determine the angle of the tow line to estimate the towing depth of the samples. For the bottom and mid-depth tows, 18 (60') and 9 m (30') of line was let out respectively, and the engine speed maintained such that the towing angle remained between 50 and 65 degrees.

Following completion of the tow, the net was washed down and contents of the collection bucket were preserved in glass quart jars in 10%

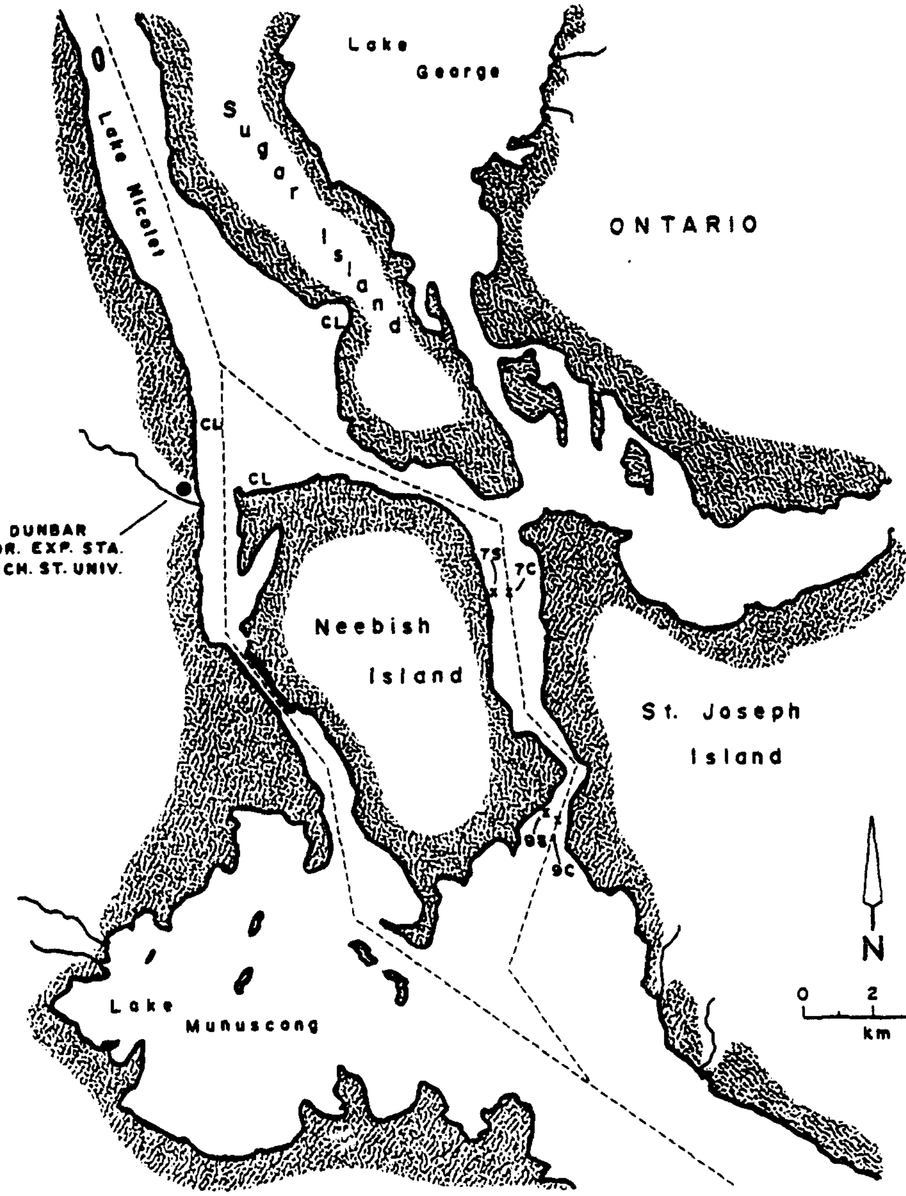

Figure 1. Locations of 1980 ichthyoplankton sampling sites in the St. Marys River near Neebish Island, Michigan. (CL=spring Coregonid larval sampling sites; S=shallow water sites near channels; C=deep channel sites) (Map by Joe Bohr)

formalin, and returned to the laboratory for sorting and identification.

Concurrent measurements of surface and bottom water temperature and dissolved oxygen were made at each station. Surface turbidity and pH samples were also collected.

Macrophyte Beds. A 0.5 m (19.7") 351 μ mesh push net was constructed, according to the design of Tarplee et al. (1979), and was used to collect ichthyoplankton samples at night along the edge of emergent macrophyte beds. A General Oceanics flowmeter (Model 2030) was mounted in the mouth of the net to estimate the amount of water filtered. A 5-minute tow time was used for each sample. Prior to completion of construction of the 0.5 m (19.7") push net by 15 July, a 1.0 m (39.4") push net was used to collect the first set of inshore samples.

Shallow Littoral Zone. A pull net was constructed in April, 1980, to collect larval fish in shallow water (less than 70 cm) (27.6") in both open and vegetated areas. The gear is a modified sheet metal snow scoop, commercially available and common in the Sault Ste. Marie, Michigan, area. The back panel was cut out, producing a rectangular mouth area of 1134 cm^2 (21 cm x 54 cm) (8.3" x 21.3"). The 78 cm (30.7") handle was reversed, and a 0.5 m (19.7") 351 μ mesh net was attached to the back of the scoop. A General Oceanics flowmeter (Model 2030) with a low speed rotor was permanently mounted in the mouth of the net using a small L brace. The gear is pulled through the water by hand. Sampling can be completed by one person, however two people facilitate both the pulling of the net as well as subsequent net rinsing and sample handling.

Prior to completion of the pull net, a D-frame net was constructed by modifying a 0.5 m (19.7") net ring and a plankton net (505 μ mesh)

was attached. This gear was used during some of the initial spring collections in the shallow littoral area.

Laboratory

Unstained samples were sorted in the laboratory under 10x magnification either in a black pan, or in a clear pyrex dish on a small light table. Fish eggs and larvae were stored in four dram vials containing modified Davidson's solution (Lam and Roff, 1977).

Identification of fish larvae was made under a Bausch and Lomb binocular microscope fitted with a polarizing filter. Standard length (tip of snout to the end of the notochord or vertebral column, depending on developmental stage) of specimens was measured to the nearest 0.1 mm using an ocular micrometer. A maximum of 20 specimens of each taxon or developmental stage were measured. All fish larvae were identified to the lowest taxonomic unit. Complete descriptions of the early life history stages of numerous species are unavailable, hence many specimens could only be identified to genus (e.g., *Etheostoma* sp., or family, e.g., Cyprinidae). Specimens too damaged to permit identification were designated unidentifiable.

Taxonomic references used in the identification of ichthyoplankton included: Cooper (1978a, 1978b), Dorr et al.(1976), Fish (1932), Hogue et al.(1976), Lam and Roff (1977), Long and Ballard (1976), Lippson and Moran (1974), Mansueti (1964), Mansueti and Hardy (1967), May and Gasaway (1967), Meyer (1970), Nelson (1968), Norden (1961, 1967) and, Faber (1970).

Data Presentation

The volume of water filtered during each 0.5 m and 1.0 m net tow was determined by first calculating the distance of the tow:

$$\text{Distance (m)} = \frac{\text{(difference in flowmeter counts)}}{999{,}999} \times \text{rotor constant}$$

where the rotor constant, supplied by the manufacturer, is 26,873 for the standard rotor and 51,020 for the low velocity rotor. The volume is then calculated as follows:

$$\begin{aligned}
\text{Volume } (m^3) &= \text{area of net mouth} \times \text{distance} \\
&= \frac{3.14\ (\text{net diameter})^2}{4} \times \text{distance} \\
&= 0.7850 \times \text{distance (1.0 m net)} \\
&= 0.1963 \times \text{distance (0.5 m net)} \\
&= 0.1134 \times \text{distance (pull net)}
\end{aligned}$$

The volume of water filtered and the number of fish larvae collected were used to estimate the density, or the number of individuals per 100 m^3. Density was calculated by multiplying the number of organisms times 100, and dividing by the volume filtered.

RESULTS

Species Composition and Abundance

A total of 162 fish larvae were collected in 17 samples from the Middle Neebish Channel, St. Marys River, from 15 July through 11 September, 1980 (Tables 2 through 14). Larvae of eight taxa were collected, with rainbow smelt larvae being the most abundant (66% of the total catch). Density of larvae was greatest in the channel collections in mid-July and declined thereafter at both stations (Table 6). Larvae appeared to be more abundant in the station 7 channel collections.

A total of 914 larvae were collected in 22 samples from the edge of the macrophyte beds at stations 7 and 9, from 3 July through 11 September, 1980 (Table 3). Rainbow smelt (27% of the total catch), yellow perch (25%), alewife (15%) and logperch (14%) larvae were the

most abundant taxa collected in the shallow water. Larvae were most abundant in the 3 July collections in the macrophyte beds at station 9 (191-316/100 m^3). These samples were collected with 1.0 m push net however, and sampled a larger area than that of later collections. There were no channel collections on this date, so comparison of abundance inshore and in the channel is not possible. However, the majority of the larvae collected (85%) during the study in 1980 were taken in the macrophyte beds as opposed to in the channel. The greatest number of larvae were collected inshore at station 9 (Table 3), accounting for 79% of all larvae collected in 1980.

In 1979, collections in tributary mouths, bays, and macrophyte beds in the St. Marys River during late summer also yielded large numbers of larvae compared to the channel (Liston et al., 1980). Cyprinid larvae were more abundant in the 1979 collections, however this may be due to differences in habitats sampled (Tables 15-17).

In 1980, percid larvae (yellow perch and logperch) were abundant when the sampling began, with cyprinid, rainbow smelt and alewife becoming more abundant in late July, August and early September. Only larvae of spring and summer spawning species were collected, owing to the time of initiation of sampling. No fish eggs were collected in 1980.

Coregonid Larvae

A total of 17 cisco and 72 lake whitefish larvae were collected in 59 quantitative samples (filtering 337.9 m^3) in the shallow littoral zone (less than 70 cm) of the St. Marys River in the vicinity of the Dunbar Research Station, Sand Island, and Sugar Island, from 13 April to 4 May, 1980 (Tables 18-28). Four of the five samples collected on 18 April near Sugar Island accounted for 36% of all the lake whitefish

larvae collected (26 specimens) during 1980. No cisco larvae were collected near Sugar Island, and no coregonid (cisco or lake whitefish) larvae were collected near Sand Island (Tables 21 and 23).

Lake whitefish larvae were first collected qualitatively on 12 April, 1980, in the littoral zone near the Dunbar Research Station using an unmetered 0.5 m (363 μ) plankton net towed by hand. One cisco larva was collected in a quantitative 1.0 m net collection in the channel at Station 9 on 3 July, 1980 (Table 5). Re-examination and identification to species of coregonid larvae collected in 1979 revealed that four lake whitefish and six cisco larvae were collected in the St. Marys River from 7 May through 26 June, 1979 (Liston et al., 1980).

DISCUSSION

Preliminary larval fish data collected in 1979 in the St. Marys River using a towed 1.0 m net (351 μ mesh) in several weed beds, bays, and tributary mouths, indicated that these areas are the nursery areas, containing concentrations of larval and juvenile fish. Comparison of nearshore data with that from deeper channel stations revealed differences in species and size composition as well as abundance. Similar studies in the St. Lawrence River imply that, in terms of ichthyoplankton, the channel region is a relative desert compared to the vegetated littoral zone, and that these littoral areas require intensive sampling and the development of quantitative sampling methods (R.G. Werner, personal communication).

The seasonal species composition and abundance of fish larvae in the Middle Neebish Channel in 1980 is similar to that seen in 1979, as well as reported by other investigations in the Great Lakes and northern temperate lakes (Faber, 1967; Amundrud et al., 1974). Larvae of fall

and winter spawners (burbot, fourhorn sculpin, cisco, lake whitefish) were absent in the channel and macrophyte bed collections owing to the time of initiation of sampling.

Lake whitefish larvae were collected in the early spring in the shallow littoral areas, and were most abundant in collections near Sugar Island (26-302/100 m^3) on 18 April (Table 21). Cisco and whitefish larvae were collected in the vicinity of the Dunbar Research Station primarily during April. Lake whitefish densities ranged from 0-250/100 m^3 and cisco from 0-193/100 m^3 in this area. The sampling effort was extremely limited. Presence of ice floes in early to mid-April prevented navigation to distant littoral areas and limited sampling primarily to the daylight hours. Initially, the collections in the vicinity of the Dunbar Research Station were conducted during the day since catch of coregonid larvae during the day was reported to be representative (Faber, 1970; Clady, 1976; Kelso and Leslie, 1979). Diurnal feeding of the coregonid larvae is reported, and they are able to feed at light intensities down to 1.5 lux (Braum, 1967). Coregonid larvae concentrate at the water surface although the reason for such behavior is disputed. Investigators have suggested positive phototropism, negative geotrophism, or simply being at the surface regardless of light conditions (Lindström, 1970; Colby and Brooke, 1973; Hoagman, 1974; Balon, 1975). However, night collections in late April produced fairly large numbers of coregonid larvae, at which time both day and night collections were initiated. Unfortunately, the abundance of larval coregonids in the pull net collections declined at this time. In addition, the sampling effort was conducted somewhat independently of any scheduled sampling.

The importance of the littoral zone as a nursery area for coregonid larvae could be related to higher water temperatures which would enhance feeding success. Water temperatures inshore near Sugar Island in mid-April ranged from 6.5 - 9.5 C, and reached 15 C in the shallow littoral zone near the Dunbar Research Station by 4 May. Braum (1967) reported a seven-fold increase in successful feeding of coregonid larvae with increasing temperature from 5.3 to 12 C. The ability of coregonid larvae to feed at reduced light intensities which would be occurring in the littoral areas at this time (as evidenced by turbid water), along with favorable temperature regimes, would make the littoral zones suitable nursery areas. Important features of a nursery area are those which enhance or insure maximum growth and activity, abundant food supply, and absence of large predators (Shenker and Dean, 1979; Smith, 1971; Thomas, 1971). Larvae may hatch out in suitable areas if drifting eggs are carried by currents into protected littoral areas. Investigations by Behmer et al. (1980) failed to locate large numbers of coregonid eggs in the St. Marys River system in areas where large numbers of ripe adults were caught. Current patterns in the river, along with tracing of movements of the large aquatic macrophytes that break up in the fall, may help locate concentrations of eggs if they are drifting, as well as give clues to suitable protected areas that would naturally serve as nursery areas for coregonids.

The biology and behavior of the larvae of other species of fish occurring or spawning in the St. Marys River was elucidated in detail in the previous report (Liston et al., 1980), and will not be repeated here. As mentioned previously, several species were collected in 1979 in the channel that were absent from the 1980 study. These include

Lampetra sp., burbot, walleye and fourhorn sculpin. The sampling period is the obvious explanation for lack of collection of larvae of the winter spawners. The absence of *Lampetra* larvae is not unusual, as they experience nocturnal drift during the summer, and few larvae (4 specimens) were collected in 1979 in the study area.

The present study, though somewhat limited in scope, indicates that the shallow littoral areas contain a greater abundance of larval fish than the channel, at least by mid-summer when the emergent and submersed vegetation has reached almost peak production. Several species were only collected at the shallow stations in 1980 and include cyprinid larvae, white sucker, *Moxostoma* sp., ninespine stickleback and yellow perch. All of these taxa were present in the 1979 channel collections, however and were most often collected earlier in the season. Only one species, carp, was collected in the channel in 1980 but not in the macrophyte beds. In 1979, carp were collected in the channel, however carp larvae were considerably more abundant in the littoral areas, 93-259/100 m^3 (Liston et al., 1980).

In 1979, sculpin larvae (*Cottus* sp.) were collected in low numbers in the channel primarily throughout July. It was speculated that these larvae may have originated elsewhere than the littoral areas. However, in 1980, sampling of these shallow areas produced cottid larvae (10-12/100 m^3) indicating that channel specimens may be the result of nocturnal drift from areas adjacent to the channel (rather than upstream) for dispersal or to facilitate feeding (Heard, 1965; Sheldon, 1968; Sinclair, 1968). Such movements may be strongly influenced by weather conditions.

The collection of large numbers of yellow perch in the littoral zone in 1980 is not surprising and is the result of larger larvae (6.3 - 10.3 mm) than were collected in the channel (5.0 - 5.7 mm) in 1979. The limnetic phase of yellow perch larvae (Houde, 1969; Nelson and Cole, 1975; Kelso and Ward, 1977) in the St. Marys River is undoubtedly more restricted spatially in the riverine system than in a lake system, and is also affected by local weather conditions. The low numbers of yellow perch larvae collected in the channel in 1979, and their absence from such collections in 1980, emphasizes the importance of the shallow areas for nursery sites.

Similarly, alewife larvae were considerably more abundant at the shallow stations than in the channel, both in 1979 and 1980. The abundance inshore may reflect the tendency of the alewife larvae to remain in the vicinity of the spawning grounds (Norden, 1961; Mansueti and Hardy, 1967). Larvae of other species collected in 1980 such as logperch, cyprinids, darters, trout-perch and ninespine sticklebacks probably behave in a similar fashion although the information is too scanty to make definitive comparisons.

The littoral areas of the St. Marys River, particularly regions of extensive macrophytes, are important nursery areas for fish throughout the ice free months, as indicated by the large numbers of larvae of commercial, sport and forage fish collected in these regions. While the aquatic macrophytes (emergent and submersed) are the major component of the primary productivity in the Middle Neebish Channel region of the St. Marys River (Liston et al., 1980), the overall productivity of the system is further enhanced through the presence of numerous attachment sites and grazing surfaces for invertebrates (Swanson et al.,

1979; Gerrish and Bristow, 1979; Keast, 1978). Macrophytes also provide cover for both vertebrate and invertebrate prey and predators (Gerrish and Bristow, 1979; Werner et al., 1978).

The assessment of impact of habitat alteration or perturbation on these areas of fish production is a tenuous process. As outlined previously (Liston et al., 1980), impacts of the proposed dredging of the St. Marys River on the early life history stages of fish may include both direct and indirect effects, the majority of which would be felt in the shallow littoral areas. Direct effects include possible exposure to toxic substances, siltation of eggs, increased turbidity and associated changes in visibility, and possible reduction in dissolved oxygen concentration. Any factors affecting the distribution, growth and survival of the aquatic macrophytes, which provide both habitat and food, will undoubtedly affect the suitability of such areas as nurseries for fish. Indirect effects of dredging may include changes in food availability or capture, decreased growth rates, increased susceptibility to predation, and changes in emmigration or immigration to and from suitable nursery areas. Both direct and indirect effects are superimposed upon natural stresses. The removal of sediment from the Middle Neebish Channel of the St. Marys River will not result in direct destruction of fish spawning ground, however, but may affect the shallow littoral nursery areas.

SUMMARY

Seasonal ichthyoplankton samples were collected in the St. Marys River near Neebish Island during 3 July through 11 September, 1980, at two general habitats within navigation courses 7 and 9: deep channel areas, and areas along the edge of macrophyte beds. Also, sampling

for whitefish larvae (Coregonidae) was carried out during 13 April to 4 May at shallow areas (less than 70 cm depth) north of Neebish Island in Lake Nicolet. The 1980 collections supplement 1979 data by providing for both annual information on "in-channel" larval abundance and comparisons between shallow and deep water abundance and composition.

Channel samples were taken at night with a 1.0 m (39.4") diameter plankton net (351μ mesh). All tows were stepped oblique tows of five minutes. A total of 162 fish larvae of eight taxa were collected in 17 samples. Rainbow smelt larvae were the most abundant (66% of total catch) followed by *Cottus* sp. (10%), alewife (8%) and johnny darter (7%). Other taxa included carp, trout-perch, *Etheostoma* sp., and logperch. Total larval abundance was highest on 15 July at 54-56 larvae per 100 m^3. Composition and abundance of larvae were similar to that seen in 1979.

Samples near macrophyte beds were taken at night with 0.5 m (19.7") 351μ mesh nets "pushed" through the water for five minutes. A total of 914 larvae of 13 taxa were collected in 22 samples. Rainbow smelt (27% of the total catch), yellow perch (25%), alewife (15%) and logperch (14%) larvae were the most abundant taxa. Other taxa included Cyprinidae sp., white sucker, *Moxostoma* sp., Catostomidae sp., trout-perch, ninespine stickleback, johnny darter, *Etheostoma* sp., and *Cottus* sp. Larvae were most abundant in 3 July collections (191-316/100 m^3). In general, fish larvae are more abundant and taxonomically diverse near beds of macrophytes compared to open water channel sites.

Sampling for whitefish larvae in Lake Nicolet was conducted mainly with "pull nets" made by modifying a metal snow scoop (mouth area=21 x 54 cm, or 8.3 x 21.3") and attaching a 0.5 m (19.7") 363μ mesh net. A total of

17 cisco and 72 lake whitefish larvae were collected in 59 samples. Lake whitefish larvae occurred in 40% of the samples. Highest densities for single samples occurred on 18 April (302 larvae/100 m^3) and on 27 April (250/100 m^3). Cisco larvae occurred in only 10.2% of the samples. Highest densities were on 25 April (193 larvae/100 m^3) and 17 April (182/100 m^3).

The importance of the shallow littoral zones and associated vegetation as nursery areas for fish in the St. Marys River in emphasized by the presence of relatively large numbers of larvae in these areas. The littoral zone is important as a nursery area, even before regrowth and peak production of the aquatic macrophytes.

Table 1. Schedule of ichthyoplankton sampling in navigation courses 7 and 9 in the St. Marys River from July through September, 1980.

	STATION							
Collection Date	7-S-1	7-S-2	7-C-1	7-C-2	9-S-1	9-S-2	9-C-1	9-C-2
3 July	+	+	a		+	+	a	
15 July	+	+	+	+				
30 July	+	+	+	+	+	+	+	+
14 August	+	+	+	+	+	+	+	+
26 August	+	+	+	+	+	+	+	+
11 September	+	+	+	+	+	+	+	+

a. Qualitative sample. Flowmeter malfunction.

Table 2. Species list of fish larvae collected in 0.5 and 1.0 m net collections in the Middle Neebish Channel and near macrophyte beds in the St. Marys River, July through September, 1980.

SCIENTIFIC NAME	COMMON NAME
Clupeidae	Herrings
Alosa pseudoharengus	Alewife
Osmeridae	Smelts
Osmerus mordax	Rainbow smelt
Cyprinidae	Minnows and carps
Cyprinus carpio	Carp
Cyprinidae	Unidentified minnow
Catostomidae	Suckers
Catostomus commersoni	White sucker
Moxostoma sp.	Unidentified redhorse
Catostomidae	Unidentified sucker
Gasterosteidae	Sticklebacks
Pungitius pungitius	Ninespine stickleback
Percopsidae	Trout-perches
Percopsis omiscomaycus	Trout-perch
Percidae	Perches
Etheostoma nigrum	Johnny darter
Etheostoma sp.	Unidentified darter
Perca flavescens	Yellow perch
Percina caprodes	Logperch
Cottidae	Sculpins
Cottus sp.	Unidentified sculpin

Table 3. Total number of fish larvae collected in 0.5 and 1.0 m net collections in the Middle Neebish Channel (C) and near macrophyte beds (S) at Stations 7 and 9 in the St. Marys River, 3 July through 11 September, 1980.

Station	7-S		9-S		7-C		9-C	
No. Collections	12		10		10		7	
Volume filtered (m^3)	804.4		638.6		820.8		540.0	
SPECIES	Number	% Total Catch	Number	% Total Catch	Number	% Total Catch	Number	% Total Catch
Alewife	10	7	141	18	6	4	7	35
Rainbow smelt	62	46	119	15	103	73	4	20
Carp	0	0	0	0	1	<1	0	0
Cyprinidae	11	8	56	7	0	0	0	0
White sucker	0	0	5	<1	0	0	0	0
Moxostoma sp.	0	0	1	<1	0	0	0	0
Catostomidae	1	<1	1	<1	0	0	0	0
Trout-perch	2	1	5	<1	4	3	2	10
Ninespine stickleback	2	1	0	0	0	0	0	0
Johnny darter	2	1	24	3	6	4	5	25
Etheostoma sp.	7	5	5	<1	1	<1	0	0
Yellow perch	0	0	270	35	0	0	0	0
Logperch	17	13	129	17	4	3	1	5
Cottus sp.	21	16	23	3	17	12	0	0
Unidentifiable	0	0	0	0	0	0	1	5
TOTAL	135		779		142		20	

Table 4. Density (No./100 m^3) of ichthyoplankton collected in 1.0 m net collections near macrophyte beds (S) and in the navigation channel (C), Station 7, St. Marys River, 3 July, 1980.

	Station			
	7-S-1	7-S-2		7-C-1
Time (h)	2318	2330	TOTAL	2245
Volume filtered (m^3)	100.2	109.7	209.9	a
Larvae				
Rainbow smelt	9	9	9	x
Ninespine stickleback	1	1	1	
Johnny darter	2	0	1	
Logperch	3	2	2	
Cottus sp.	10	10	10	x
Unidentifiable	0	0	0	x
TOTAL	25	22	23	

[a]Qualitative sample due to flowmeter malfunction. x indicates species occurrence.

Table 5. Density (No./100 m^3) of ichthyoplankton collected in 1.0 m net collections near macrophyte beds (S) and in the navigation channel (C), Station 9, St. Marys River, 3 July, 1980.

	Station			
	9-S-1	9-S-2		9-C-1
Time (h)	0018	0030	TOTAL	0050
Volume filtered (m^3)	111.7	100.3	212.0	a
Larvae				
Cisco	0	0	0	x
Rainbow smelt	27	66	46	x
White sucker	2	3	2	x
Cyprinidae	5	1	3	
Trout-perch	2	2	2	x
Ninespine stickleback	0	0	0	x
Johnny darter	17	5	11	x
Etheostoma sp.	1	3	2	
Yellow perch	155	96	127	
Logperch	96	3	52	x
Cottus sp.	10	12	11	x
TOTAL [b]	316	191	257	

[a] Qualitative sample due to flowmeter malfunction. x indicates species occurrence.

[b] Total for each column may not equal sum of densities for all species due to rounding of numbers.

Table 6. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 15 July, 1980.

	Station					
	7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2210	2226	TOTAL	2240	2257	TOTAL
Volume filtered (m^3)	65.1	60.1	125.2	114.0	102.4	216.4
Larvae						
Rainbow smelt	6	13	10	46	43	45
Trout-perch	0	0	0	1	1	1
Johnny darter	0	0	0	3	0	1
Etheostoma sp.	0	0	0	0	1	a
Logperch	3	10	6	1	0	a
Cottus sp.	0	0	0	7	9	8
TOTAL[b]	9	23	16	56	54	56

[a]Less than 1 specimen/100 m^3.

[b]Total for each column may not equal sum of densities for all species due to rounding of numbers.

Table 7. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 30 July, 1980.

	Station					
	7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	0003	0011	TOTAL	2329	2340	TOTAL
Volume filtered (m^3)	54.4	47.6	102.0	84.8	88.7	173.5
Larvae						
Alewife	0	0	0	1	0	1
Rainbow smelt	2	2	2	4	2	3
Catostomidae	0	2	1	0	0	0
Carp	0	0	0	0	1	1
Cyprinidae	15	6	11	0	0	0
Trout-perch	0	4	2	0	1	1
Johnny darter	0	0	0	2	1	2
Etheostoma sp.	6	8	7	0	0	0
Logperch	4	4	4	0	3	2
TOTAL [a]	26	27	26	7	9	8

[a] Total for each column may not equal sum of densities for all species due to rounding of numbers.

Table 8. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 30 July, 1980.

	Station					
	9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	2226	2235	TOTAL	2250	2305	TOTAL
Volume filtered (m^3)	57.2	50.3	107.5	79.0	97.4[a]	176.4
Larvae						
Alewife	17	18	18	0	0	0
Rainbow smelt	17	2	10	0	1	1
White sucker	2	0	1	0	0	0
Catostomidae	0	2	1	1	0	1
Cyprinidae	37	16	27	3	2	2
Trout-perch	0	0	0	0	1	1
Johnny darter	0	0	0	4	5	5
Etheostoma sp.	1	0	1	0	0	0
Logperch	14	22	18	0	1	1
Unidentifiable	0	0	0	0	1	1
TOTAL[b]	89	60	75	8	11	10

[a]Portion of sample spilled in laboratory.

[b]Total for each column may not equal sum of densities for all species due to rounding of numbers.

Table 9. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 14 August, 1980.

	Station					
	7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2330	2340	TOTAL	2305	2315	TOTAL
Volume filtered (m^3)	58.6	52.0	110.6	80.4	96.5	176.9
Larvae						
Alewife	2	6	4	4	1	2
Rainbow smelt	5	0	3	1	0	1
Trout-perch	0	0	0	1	0	1
TOTAL [a]	7	6	6	6	1	3

[a] Total for each column may not equal sum of densities for all species due to rounding of numbers.

Table 10. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 14 August, 1980.

	Station					
	9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	2155	2205	TOTAL	2233	2243	TOTAL
Volume filtered (m^3)	51.0	58.4	109.4	75.7	35.6	111.6
Larvae						
Alewife	108	22	62	4	8	5
Rainbow smelt	8	5	6	3	0	2
Cyprinidae	24	9	16	0	0	0
Trout-perch	2	0	1	1	0	1
Yellow perch	0	2	1	0	0	0
TOTAL [a]	141	38	86	8	8	8

[a]Total for each column may not equal sum of densities for all species due to rounding of numbers.

Table 11. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in the navigation channel (C), Station 7, St. Marys River, 26 August, 1980.

	Station					
	7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2235	2243	TOTAL	2210	2220	TOTAL
Volume filtered (m^3)	59.4	59.1	118.5	42.2	68.2	110.4
Larvae						
Alewife	0	2	1	0	0	0
Rainbow smelt	30	5	18	0	0	0
TOTAL	30	7	19	0	0	0

Table 12. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in the navigation channel (C), Station 9, St. Marys River, 26 August, 1980.

	Station					
	9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	2115	2125	TOTAL	2135	2150	TOTAL
Volume filtered (m^3)	53.9	54.1	108.0	72.4	79.2	151.6
Larvae						
Alewife	24	72	48	1	0	1
Rainbow smelt	2	4	3	1	0	1
Cyprinidae	0	6	3	0	0	0
TOTAL [a]	26	81	54	3	0	1

[a] Total for each column may not equal sum of densities for all species due to rounding of numbers.

Table 13. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in the navigation channel (C), Station 7, St. Marys River, 11 September, 1980.

	Station					
	7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2300	2310	TOTAL	2232	2245	TOTAL
Volume filtered (m^3)	61.2	77.0	138.2	61.3	82.3	143.6
Larvae						
Alewife	5	1	3	2	0	1
Rainbow smelt	7	1	4	0	0	0
TOTAL [a]	11	3	7	2	0	1

[a]Total for each column may not equal sum of densities for all species due to rounding of numbers.

Table 14. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in the navigation channel (C), Station 9, St. Marys River, 11 September, 1980.

	Station					
	9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	2102	2139	TOTAL	2150	2207	TOTAL
Volume filtered (m^3)	42.7	59.0	101.7	85.4	94.3	179.7
Larvae						
Alewife	5	0	2	0	0	0
TOTAL	5	0	2	0	0	0

Table 15. Density (No./100 m^3) of ichthyoplankton collected in 1.0 m net collections near macrophyte beds in the St. Marys River in the vicinity of the Dunbar Research Station, July through October, 1979.

Date	23 July	3 August	5 September	8 October
Time (h)	2300	2000	2108	2045
Volume filtered (m^3)	94.3	74.4	500.7	340.9
Larvae				
Alewife	46	30	1	12
Rainbow smelt	3	4	1	0
Carp	2	0	0	0
Cyprinidae[a]	93	66	0	1
Trout-perch	2	0	0	0
Ninespine stickleback	0	4	0	0
Johnny darter	1	0	0	0
Yellow perch	5	12	0	0
Logperch	14	23	0	0
TOTAL[b]	166	138	1	12

[a]More than one species.

[b]Total for each column may not equal sum of densities for all species due to rounding of numbers.

Table 16. Density (No./100 m^3) of ichthyoplankton collected in 1.0 m net collections in the mouth of Two Tree River, near navigation course 9, in the St. Marys River, July and August, 1979.

Date	29 July	30 August
Time (h)	2155	2156
Volume filtered (m^3)	263.5	352.0
Larvae		
Alewife	5	3
Carp	1	0
Cyprinidae	168	17
Catostomidae	<1	0
Trout-perch	1	<1
Rock bass	4	0
Etheostoma sp.	3	0
Yellow perch	7	0
Logperch	7	0
TOTAL[a]	196	20
Juveniles		
Alewife	0	<1
Carp	<1	0
Cyprinidae	1	<1
Trout-perch	2	3
Rock bass	2	<1
Yellow perch	<1	0
TOTAL[a]	5	4

[a]Total for each column may not equal sum of densities for all species due to rounding of numbers.

Table 17. Density (No./100 m^3) of ichthyoplankton collected in 1.0 m net collections in Mirre Point Bay, near navigation course 8 in the St. Marys River, 29 July, 1979.

Time (h)	2240
Volume filtered (m^3)	196.6
Larvae	
Alewife	2
Carp	1
Cyprinidae	259
Catostomidae	2
Trout-perch	1
Rock bass	<1
Johnny darter	2
Etheostoma sp.	18
Yellow perch	86
Logperch	46
Walleye	2
TOTAL	420
Juveniles	
Catostomidae	5
TOTAL	5

Table 18. Density (No./100 m^3) of lake whitefish larvae collected with a D-net (505 μ mesh) in the littoral zone of the St. Marys River in the vicinity of the Dunbar Research Station, 13 April, 1980.

Replicate	1	2	3	
Time (h)	1515	1535	1555	TOTAL
Volume filtered (m^3)	67.2	53.0	24.6	144.8
Larvae	1	9	0	4

Table 19. Density (No./100 m^3) of lake whitefish larvae collected with a push net (363 μ mesh) in the littoral zone of the St. Marys River in the vicinity of the Dunbar Research Station, 15 April, 1980.

Replicate	1	2	3	
Time (h)	1745	1800	1812	TOTAL
Volume filtered (m^3)	2.9	4.4	2.8	10.1
Larvae	34	0	0	10

Table 20. Density (No./100 m^3) of coregonid larvae collected with a push net (505 μ mesh) in the littoral zone of the St. Marys River in the vicinity of the Dunbar Research Station, 17 April, 1980.

Replicate	1	2	3	4	5
Time (h)	1520	-	-	-	-
Volume filtered (m^3)	1.2	1.8	1.1[a]	2.0	3.4
Cisco	0	0	182	0	0
Lake whitefish	0	0	91	0	29
TOTAL	0	0	273	0	29

[a]Sample collected following vessel passage.

Table 21. Density (No./100 m^3) of lake whitefish larvae collected with a pull net (505 μ mesh) in the littoral zone of the St. Marys River near Sugar Island, in the vicinity of navigation course 6, 18 April, 1980.

Replicate	1	2	3	4	5
Time (h)	-	1340	1355	1420	1500
Volume filtered (m^3)	3.2	7.2	4.3	3.8	7.1
Larvae	0	42	302	26	127

Table 22. Density (No./100 m^3) of lake whitefish larvae collected with a pull net (505 μ mesh) in the littoral zone of the St. Marys River in the vicinity of the Dunbar Research Station, 18 April, 1980.

Replicate	1	2	3	4	5
Time (h)	1605	1615	-	1645	1703
Volume filtered (m^3)	5.8	5.7	.5	7.5	5.7
Larvae	69	35	0	13	0

Table 23. Density (No./100 m^3) of coregonid larvae collected with a pull net (363 μ mesh) in the littoral zone of the St. Marys River, near Sand Island, 21 April, 1980.

Substrate	sand	clay	rocks
Volume filtered (m^3)	3.1	1.1	2.9
Larvae	0	0	0

Table 24. Density (No./100 m^3) of coregonid larvae collected with a pull net (363 μ mesh) in the littoral zone of the St. Marys River in the vicinity of the Dunbar Research Station, 25 April, 1980.

	Station					
	0	1	2	3	4	5
Time (h)	1245	1305	1335	1410	1500	1517
Volume filtered (m^3)	5.4	5.7	5.4	6.2	4.9	4.6
Cisco	0	193	19	16	0	0
Lake whitefish	37	35	19	16	0	0
TOTAL [a]	37	228	37	32	0	0

[a]Total for each column may not equal sum of densities for all species due to rounding of numbers.

Table 25. Density (No./100 m^3) of coregonid larvae collected with a pull net (363 μ mesh) in the littoral zone of the St. Marys River in the vicinity of the Dunbar Research Station, 27 April, 1980.

	Station			
	0	1	2	3
Time (h)	1445	1500	1515	1525
Volume filtered (m^3)	2.6	3.5	2.8	0.4[a]
Cisco	0	57	0	0
Lake whitefish	38	0	0	250
TOTAL	38	57	0	250

[a]Towed with the wind.

Table 26. Density (No./100 m^3) of coregonid larvae collected with a pull net (363 μ mesh) in the littoral zone of the St. Marys River in the vicinity of the Dunbar Research Station, 27 April, 1980.

	Station 0	Station 1	Station 2
Time (h)	2125	2138	2200
Volume filtered (m^3)	5.5	5.3	4.5
Cisco	0	19	0
Lake whitefish	218	57	89
TOTAL[a]	218	75	89

[a]Total for each column may not equal sum of densities for all species due to rounding of numbers.

Table 27. Density (No./100 m^3) of coregonid larvae collected with a pull net (363 μ mesh) in the littoral zone of the St. Marys River in the vicinity of the Dunbar Research Station, 4 May, 1980.

	Station										
	A	B	C	D	3	5	6	7	8	9	10
Time (h)	1255	1246	1235	1230	1200	1020	1045	1056	1112	1130	1145
Volume filtered (m^3)	2.2	2.0	1.9	1.7	3.9	2.7	2.1	2.7	2.1	2.3	2.3
Cisco	0	0	0	0	0	0	0	0	0	0	0
Lake whitefish	0	0	53	59	0	0	0	0	0	0	0
TOTAL	0	0	53	59	0	0	0	0	0	0	0

Table 28. Density (No./100 m^3) of coregonid larvae collected with a pull net (363 μ mesh) in the littoral zone of the St. Marys River in the vicinity of the Dunbar Research Station, 3-4 May, 1980.

	Station										
	A	B	C	D	0	1	2	4	5	6	7
Time (h)	2241	2230	2220	2210	2250	2305	2323	0030	2205	2220	2237
Volume filtered (m^3)	2.6	2.2	2.8	2.3	4.4	2.8	4.3	3.6	2.4	2.9	2.6
Larvae	0	0	0	0	0	0	0	0	0	0	0

JUVENILE AND ADULT FISH

METHODS AND MATERIALS

Sampling stations were established in the Middle Neebish Channel, St. Marys River, in navigation course 7 on the east shore of Neebish Island and in navigation course 10 off Rocky Point in Lake Munuscong (Figure 1). Station sites were selected to reflect fish populations inhabiting a narrow channel area (course 7) and a habitat with more open water adjacent the channel (course 10). Shortly after initiation of summer sampling, conflicts with local sport fishermen arose concerning gill netting. Because of this we felt that it would be prudent to relocate sampling stations. The station at navigation course 7 was relocated approximately one kilometer (.62 mi) north of the original site and the station at course 10 was relocated in course 9 of Lake Munuscong (Figure 1). This allowed continued pursuit of our goals and minimized alienation of residents. In addition, a nearshore site in Lake Nicolet was used to augment trap netting and shore seining (Figure 1).

An offshore and nearshore site was selected at each station for comparison of horizontal distribution of fish. Offshore sites at both stations were located adjacent the shipping channel. Nearshore sites were in areas extending from the shoreline out to a depth of two meters.

Sampling Seasons

Sampling for adult and juvenile fish was conducted during February and March and then June through November. February and March samples are considered as winter samples, June through August 31 samples as summer samples, and 1 September through November samples as fall samples.

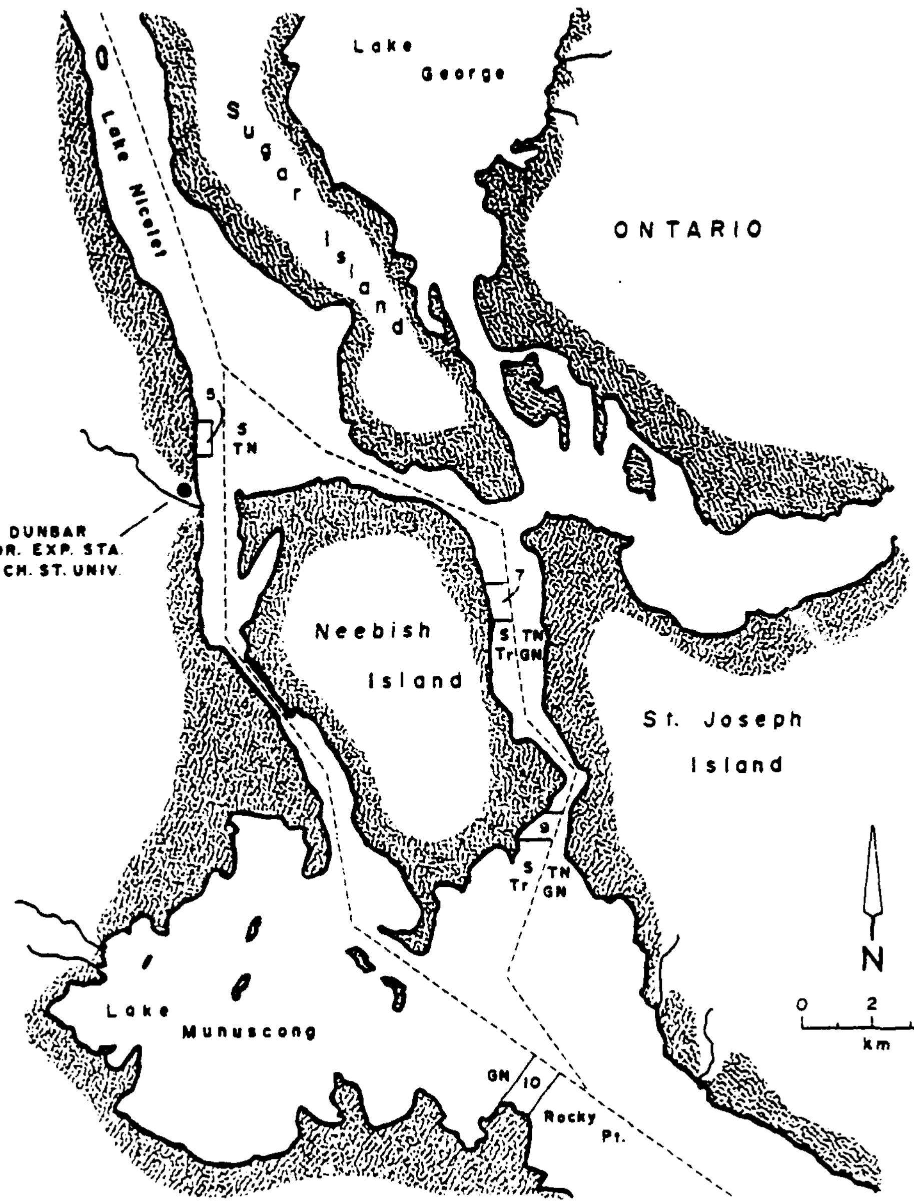

Figure 1. Map of the St. Marys River near Neebish Island showing juvenile and adult fish sampling stations. (Stations 5, 7, 9, and 10). (S=shoreline seine; TN=trap net; Tr=trawl; GN=gill net).

Gear

The primary sampling gear used for seasonal comparison of relative abundance of fish was the experimental bottom gill net. Supplemental gear included bottom trawls, trap nets and beach seines.

Bottom Gill Net. Each experimental bottom gill net consisted of 15.2 x 1.8 m (50' x 6') panels of 25 (1"), 51 (2"), 63 (2½"), 76 (3"), 102 (4"), 114 (4½") and 178 mm (7") stretched mesh nylon with No. 69 twine size. Total net length was seven panels or 106.4 m (350'). During winter, nets were set in the morning and retrieved approximately 24 hours later. During periods of open water (summer and fall), nets were set prior to sunset and retrieved in the morning after sunrise approximately 12 hours later. On each sampling date two nets were set for the same period at each station with one net set offshore and the other set nearshore. A total of 72 gill net sets were made (Table 1).

Catches of the most abundant species from nearshore and offshore gill nets were analyzed statistically using the non-parametric Kruskal-Wallis H-Test. A probability level of 5% was used to determine if the catches differed significantly.

Bottom trawl. Bottom trawl samples were collected at night with a semi-balloon otter trawl having a 4.9 m (16') head rope, 38 mm (1.5") stretched mesh body and 3 mm (.1") bar mesh cod end liner. Each sample consisted of towing the trawl for 5 minutes behind a 16 ft. Boston Whaler powered by a 70 horsepower outboard.

Sixteen trawl samples were collected during July through October (Table 1). Samples were collected at the 1.5 m (5') (nearshore) and 3.1 m (10') (offshore) depth contours of each station.

Table 1. Monthly number of fish samples taken from the Middle Neebish Channel, St. Marys River, during 1980.

Season-Month	Gill Net	Trawl	Trap Net	Seine
	Gear Type			
Winter				
February	32			
March	8			
Summer				
June	2			
July	8	4		2
August	4	4	2*	
Fall				
September	6	4	8	
October	8	4	10	3
November	4			

*Trap net samples collected on 28 August are analyzed with fall data in the text.

Trap net. Trap net samples were collected with a net constructed of 6.35 mm (.25") bar mesh nylon having 15.2 x 1 m (50 x 3.3') lead, 2.2 x 1 m (7.2 x 3.3') wings, a 1 m^2 (10.8 ft^2) pot and a single heart, similar to the design of Beamish (1972). A trap net sample consisted of setting the gear for either the entire light or dark period of a day (the August sample from course 7 was abbreviated by weather conditions).

Samples were collected nearshore in emergent vegetation and in open water. A total of 16 trap net samples were collected at three sampling locations in August, September and October (Figure 1; Table 1).

Shoreline seine. A 61 x 1.8 m (200 x 6') bag seine (6.35 mm bar mesh) (.25") was used to collect fish along the shoreline of both sampling stations and at a site in navigation course 5. The seine was employed by holding one end along shore while pulling the remainder of the seine out and down shore so as to form a rectangle of approximately 465 m^2 (5,000 ft^2). All seine samples were taken at night. A total of five seine samples were collected in July and October (Table 1).

Field and Laboratory Analysis of Fish Collections

The total number and total weight (g) of each fish species was recorded for each net sample. Adult fish were released alive whenever possible. Data recorded for each released individual were length, weight, and at certain times of the year, sex (i.e., spawning periods). Fish not released were returned to the laboratory. A random sample of 10 to 20 individuals of each species was selected and individuals were measured for total length (mm), weight (g), sex and condition of gonads.

In addition, stomachs were removed from cisco, northern pike, walleye, and yellow perch individuals for food habit determinations. Stomachs were

preserved individually in 10% formalin. Analysis of stomach contents included identifying food organisms and recording the number, weight (g), and volume (ml) for each food category.

RESULTS

A total of 6,020 individual fish representing 44 species were collected during 1980. The bottom trawl caught the greatest number of individuals while trap netting captured the most species (Table 2). As each gear type was somewhat selective, results of catches are presented by gear type and season.

Bottom Gill Nets

Winter. A total of 140 fish representing 11 species were collected from 40 gill net sets during February and March. Overall, cisco comprised 40.0% of the catch, northern pike and white sucker each 14.3%, yellow perch 10.7%, and walleye 9.3%. Definite patterns in fish distribution were noted in each sampling area.

At navigation course 7, 62 of 78 fish were taken in the nearshore nets (Tables 3 and 4). The most abundant species at course 7 were cisco (35.9%), white sucker (20.5%), yellow perch (15.4%) and northern pike (14.1%).

In Lake Munuscong, 47 of 62 fish were captured in the offshore nets (Tables 5 and 6). The most abundant species were cisco (45.2%), walleye (19.4%), northern pike (14.5%), and white sucker (6.5%).

Non-parametric statistical analysis (Kruskal-Wallis H-Test) indicated that statistically significant ($P<0.05$) differences existed in catches of two of the [illegible] common species in combined nearshore versus offshore collections (Tab[illegible]). Differences in catches of cisco and yellow perch

Table 2. Summary of numbers and species of fish collected in the St. Marys River during 1980.

Species	Gill Net	Trawl	Trap Net	Seine	Total
Longnose gar	4				4
Alewife	28				28
Chinook salmon	1				1
Rainbow trout	1				1
Cisco	268	2			270
Rainbow smelt	10	181		1	192
Northern pike	92	4	1		97
Central mudminnow			5		5
Carp	7		1		8
Blackchin shiner			2		2
Blacknose shiner		6	131	2	139
Common shiner		4	27	15	46
Emerald shiner	6	6	7	107	126
Golden shiner			4		4
Mimic shiner		292	5	9	306
Rosyface shiner				2	2
Sand shiner		11	194	3	208
Spottail shiner	23	533	44	64	664
Lake chub			13	7	20
Blacknose dace				1	1
Longnose dace				3	3
Bluntnose minnow			19		19
Longnose sucker	1				1
White sucker	217	172	130	1	520
Shorthead redhorse	17				17
Silver redhorse	8			3	11
Brown bullhead	25	1	268		294
Channel catfish	1				1
Brook stickleback		132	6		138
Ninespine stickleback		87	3		90
Trout-perch	8	695	1	58	762
Burbot	6				6
Banded killifish			1		1
Bluegill			169		169
Pumpkinseed	1				1
Rock bass	77	17	42	10	146
Smallmouth bass	6	2	2		10
Iowa darter		4			4
Johnny darter		704	7	7	718
Logperch		48	9	1	58
Yellow perch	135	185	154	5	479
Walleye	46	9		9	64
Mottled sculpin		289	6		295
Slimy sculpin		88		1	89
Total	988	3472	1251	309	6020
n	72	16	16	5	
Number species	23	23	26	20	44

Table 3. Number of fish collected with experimental bottom gill nets in shallow (1.5 - 2.0 m) water of navigation course 7, Middle Neebish Channel, St. Marys River, 19 February through 5 March, 1980.

	Date										
	February							March			
Species	19	20	21	25	26	27	28	3	4	5	Total
Cisco	8	4	0	0	7	1	0	3	2	1	26
Rainbow smelt	0	0	0	0	0	0	0	1	0	1	2
Northern pike	0	2	2	3	0	0	1	0	1	0	9
White sucker	0	6	2	0	0	0	0	1	1	0	10
Burbot	1	0	0	0	0	0	1	0	0	0	2
Trout-perch	0	1	0	0	0	0	0	0	0	0	1
Yellow perch	1	4	2	0	2	1	1	1	0	0	12
Daily total	10	17	6	3	9	2	3	6	4	2	62 Seasonal total
Number species	3	5	3	1	2	2	3	4	3	2	7

Table 4. Number of fish collected with experimental bottom gill nets in deep (5.0 m) water of navigation course 7, Middle Neebish Channel, St. Marys River, 19 February through 5 March, 1980.

Species	Date: February 25	26	27	28	29	March 1	2	3	4	5	Total	
Cisco	0	0	0	0	0	0	1	0	0	1	2	
Rainbow smelt	0	0	0	0	1	1	0	1	0	0	3	
Northern pike	0	1	1	0	0	0	0	0	0	0	2	
White sucker	1	1	0	1	0	0	2	1	0	0	6	
Burbot	0	0	0	0	1	0	0	0	0	0	1	
Yellow perch	0	1	0	0	0	0	0	0	0	0	1	
Walleye	0	0	1	0	0	0	0	0	0	0	1	
Daily total	1	3	2	1	2	1	3	2	0	1	16	Seasonal total
Number species	1	3	2	1	2	1	2	2	0	1	7	

Table 5. Number of fish collected with experimental bottom gill nets in shallow water (1.5 - 2.0 m) of Lake Munuscong, St. Marys River, 12 through 27 February, 1980.

Species	February										Total	
	12	13	14	18	19	20	21	25	26	27		
Longnose gar	1	1	1	0	0	0	0	0	0	0	3	
Cisco	0	0	1	0	1	0	1	0	0	0	3	
Northern pike	1	0	1	1	1	0	0	0	0	0	4	
Spottail shiner	0	0	0	0	0	0	1	0	0	0	1	
White sucker	0	0	0	1	0	0	0	0	0	0	1	
Yellow perch	0	1	0	0	1	0	0	0	0	0	2	
Walleye	0	0	1	0	0	0	0	0	0	0	1	
Daily total	2	2	4	2	3	0	2	0	0	0	15	Seasonal total
Number species	2	2	4	2	3	0	2	0	0	0	7	

Table 6. Number of fish collected with experimental bottom gill nets in deep water (6.0 m) of Lake Munuscong, St. Marys River, 11 through 26 February, 1980.

	February											
Species	11	12	13	14	18	19	20	21	25	26	Total	
Cisco	0	1	1	0	6	7	4	0	4	2	25	
Northern pike	2	0	3	0	0	0	0	0	0	0	5	
Carp	0	0	0	0	0	0	0	0	2	0	2	
White sucker	2	0	0	0	0	0	0	0	0	1	3	
Burbot	0	0	0	0	0	1	0	0	0	0	1	
Walleye	0	1	0	1	0	2	3	1	3	0	11	
Daily total	4	2	4	1	6	10	7	1	9	3	47	Seasonal total
Number species	2	2	2	1	1	3	2	1	3	2	6	

Table 7. Summary of statistical analysis of 1980 gill net catches from nearshore verses offshore sites in channel course 7 and Lake Munuscong, St. Marys River. NS = not significant, S = significant at the 0.05 level.

Species	Winter n	Kruskal-Wallis H Statistic	
Cisco	40	9.45	S
Northern pike	40	1.84	NS
White sucker	40	2.63	NS
Yellow perch	40	8.90	S
Walleye	40	6.58	NS

Species	Open Water n	Kruskal-Wallis H Statistic	
Cisco	32	3.45	NS
Northern pike	32	6.06	NS
White sucker	32	2.35	NS
Rock bass	32	10.95	S
Yellow perch	32	3.08	NS
Walleye	32	5.08	NS

For all cases degrees of freedom = 3 and X^2 .05 [3df] = 7.82

were significant whereas catches of northern pike, white sucker and walleye were judged similar ($P<0.05$). Cisco were more abundant offshore in Lake Munuscong and both cisco and yellow perch were more abundant at the near-shore site of course 7 than at the offshore site. Only two yellow perch were collected in Lake Munuscong and both were taken at the nearshore site.

Summer. A total of 492 fish representing 19 species were collected from 14 gill net sets during June through August. Two hundred and fifty-eight fish were collected from navigation course 7 and 234 from Lake Munuscong. Species comprising greater than 5% of the summer catch included white sucker (25.2%), cisco (18.9%), yellow perch (16.1%), northern pike (6.9%), rock bass (5.3%) and alewife (5.3%). Walleye, spottail shiner and brown bullhead comprised 4.3%, 4.2% and 4.1% of the summer collections respectively.

At navigation course 7, 153 fish representing 12 species were collected at the nearshore site while 105 fish representing 7 species were taken at the offshore site (Tables 8 and 9). Predominant species included cisco, yellow perch and white sucker comprising 35.7%, 22.9% and 21.7% of the catch respectively. Northern pike represented 5.4% of the catch.

In Lake Munuscong, 151 fish representing 15 species were collected nearshore and 83 fish representing 13 species were taken offshore (Tables 10 and 11). Predominant species included white sucker (45.0%), alewife (15.9%), rock bass (13.9%). northern pike (13.3%), yellow perch (13.3%), and brown bullhead (11.9%). Species comprising between 5 - 10% of the catch included shorthead redhorse, walleye, and spottail shiner.

Table 8. Number of fish collected with experimental bottom gill nets in shallow water (1.5 - 2.0 m) of navigation course 7, Middle Neebish Channel, St. Marys River during June, July and August, 1980.

Species	June 23	July 11	July 15	August 26	Total	
Alewife	0	0	0	2	2	
Cisco	6	0	47	1	54	
Rainbow smelt	1	0	0	0	1	
Northern pike	0	0	2	0	2	
Spottail shiner	0	1	9	0	10	
White sucker	6	6	13	4	29	
Shorthead redhorse	0	0	0	1	1	
Brown bullhead	1	1	0	0	2	
Trout-perch	1	0	5	0	6	
Rock bass	1	1	2	0	4	
Yellow perch	1	2	26	5	34	
Walleye	6	1	1	0	8	
Daily Total	23	105	12	13	153	Seasonal Total
Number species	8	8	6	5	12	

Table 9. Number of fish collected with experimental bottom gill nets in deep water (5.0 m) of navigation course 7, Middle Neebish Channel, St. Marys River during June, July and August, 1980.

Species	June 23	July 11	July 15	August 26	Total
Cisco	32	0	6	0	38
Northern pike	5	1	5	1	12
Spottail shiner	0	1	0	0	1
White sucker	6	12	7	2	27
Rock bass	0	0	1	0	1
Yellow perch	6	2	16	1	25
Walleye	0	1	0	0	1
Daily Total	49	35	17	4	105 Seasonal Total
Number species	4	5	5	3	7

Table 10. Number of fish collected with experimental bottom gill nets in shallow water (1.5 - 2.0 m) of Lake Munuscong, St. Marys River during July and August, 1980.

Species	July 1	July 30	August 18	Total	
Longnose gar	0	0	1	1	
Alewife	1	18	0	19	
Rainbow smelt	0	1	0	1	
Northern pike	5	2	0	7	
Carp	1	1	1	3	
Emerald shiner	4	2	0	6	
Spottail shiner	7	3	0	10	
White sucker	12	27	6	45	
Shorthead redhorse	0	12	2	14	
Silver redhorse	0	0	4	4	
Brown bullhead	0	5	3	8	
Rock bass	8	5	3	16	
Smallmouth bass	0	3	1	4	
Yellow perch	2	1	0	3	
Walleye	3	2	5	10	
Daily total	43	82	26	151	Seasonal Total
Number species	9	13	9	15	

Table 11. Number of fish collected with experimental bottom gill nets in deep water (5.0 - 6.0 m) of Lake Munuscong, St. Marys River during July and August, 1980.

Species	July 1	July 30	August 18	Total	
Alewife	0	5	0	5	
Cisco	1	0	0	1	
Northern pike	4	7	2	13	
Carp	0	0	2	2	
White sucker	4	12	7	23	
Longnose sucker	0	1	0	1	
Channel catfish	0	0	1	1	
Brown bullhead	0	9	1	10	
Trout-perch	1	0	0	1	
Rock bass	0	4	1	5	
Smallmouth bass	0	2	0	2	
Yellow perch	1	13	3	17	
Walleye	2	0	0	2	
Daily total	13	53	17	83	Seasonal Total
Number species	6	8	7	13	

Fall. A total of 356 fish representing 16 species were collected from 18 gill net sets during fall. One hundred and forty-eight fish were collected in navigation course 7 and 208 fish in Lake Munuscong. Overall, cisco comprised 33.4% of the fall catch. Other species comprising greater than 5% of the fall catch were white sucker (20.5%), rock bass (14.3%), yellow perch (11.5%) and northern pike (10.7%).

In navigation course 7, 78 fish were collected at the nearshore site while 70 were collected offshore. Cisco were present in 8 out of 10 nets set and comprised 39.9% of the catch (Tables 12 and 13). White sucker (27.7%), northern pike (14.9%) and yellow perch (8.1%) comprised most of the remainder of fall collections.

In Lake Munuscong, fall collections (species combined) were also similar at nearshore and offshore sites (Tables 14 and 15). Cisco and rock bass comprised 28.8% and 24.0% of the catch respectively. However, 41 of 60 cisco were taken nearshore while 41 of 50 rock bass collected were taken offshore. White sucker (15.4%), yellow perch (13.9%) and northern pike (7.7%) were also common in samples. The remaining 10.1% of the collections was comprised of 9 other species.

Statistical analysis of catches of six common species (white sucker, cisco, yellow perch, northern pike, rock bass and walleye) collected during open water periods (summer and fall) was conducted using the Kruskal-Wallis H-Test. Results indicated that only rock bass exhibited significant ($P<0.05$) differences in spatial distribution (Table 7).

Table 12. Number of fish collected with experimental bottom gill nets in shallow water (1.5 - 2.0 m) of navigation course 7, Middle Neebish Channel, St. Marys River, during September, October and November, 1980.

Species	September		October		November	Total	
	24	29	14	20	12		
Cisco	11	0	5	7	12	35	
Northern pike	0	3	1	2	1	7	
White sucker	11	2	5	7	2	27	
Shorthead redhorse	0	0	1	0	0	1	
Silver redhorse	1	0	0	1	0	2	
Yellow perch	1	0	0	0	1	2	
Walleye	1	3	0	0	0	4	
Daily Total	25	8	12	17	16	78	Seasonal Total
Number Species	5	3	4	4	4	7	

Table 13. Number of fish collected with experimental bottom gill nets in deep water (5. 0 m) of navigation course 7, Middle Neebish Channel, St. Marys River, during September, October, and November, 1980.

Species	September 24	September 29	October 14	October 20	November 12	Total	
Cisco	2	6	0	3	13	24	
Rainbow trout	0	0	0	1	0	1	
Northern pike	1	5	3	4	2	15	
Spottail shiner	0	1	0	0	0	1	
White sucker	2	1	8	2	1	14	
Brown bullhead	1	0	0	0	0	1	
Burbot	0	0	0	0	1	1	
Rock bass	0	1	0	0	0	1	
Yellow perch	1	7	2	0	0	10	
Walleye	0	0	1	1	0	2	
Daily Total	7	21	14	11	17	70	Seasonal Total
Number species	5	6	4	5	4	10	

Table 14. Number of fish collected with experimental bottom gill nets in shallow water (1.5 - 2.0 m) of Lake Munuscong, St. Marys River, d ring September, October and November, 1980.

Species	September	October		November	Total	
	8	9	21	5		
Cisco	0	5	4	32	41	
Chinook salmon	0	1	0	0	1	
Rainbow smelt	0	1	1	0	2	
Northern pike	0	5	3	2	10	
White sucker	4	5	7	2	18	
Shorthead redhorse	0	0	1	0	1	
Silver redhorse	0	0	1	0	1	
Brown bullhead	1	1	0	0	2	
Pumpkinseed	1	0	0	0	1	
Rock bass	5	1	3	0	9	
Yellow perch	0	1	4	0	5	
Walleye	1	4	0	0	5	
Daily Total	12	24	24	36	96	Seasonal Total
Number species	5	9	8	3	12	

Table 15. Number of fish collected with experimental bottom gill nets in deep water (5.0 m) of Lake Munuscong, St. Marys River, during September, October, and November, 1980.

Species	September 8	October 9	October 21	November 5	Total	
Alewife	0	2	0	0	2	
Cisco	0	0	4	15	19	
Rainbow smelt	0	1	0	0	1	
Northern pike	2	3	0	1	6	
White sucker	11	2	1	0	14	
Silver redhorse	0	0	1	0	1	
Brown bullhead	1	1	0	0	2	
Burbot	1	0	0	0	1	
Rock bass	38	0	1	2	41	
Yellow perch	4	19	1	0	24	
Walleye	1	0	0	0	1	
Daily Total	58	28	8	18	112	Seasonal Total
Number Species	7	6	5	3	11	

Bottom Trawl

Summer. A total of 2,302 fish representing 21 species were collected in 8 trawl samples during summer. Overall, trout-perch were the most abundant comprising 27.4% of the total catch (Table 16). Other numerically important species included spottail shiner (18.7%), johnny darter (14.5%), mottled sculpin (9.6%), yellow perch (7.0%), white sucker (6.6%), and mimic shiner (4.8%).

At navigation course 7, 557 fish were collected at the offshore site and 394 fish were collected nearshore. Dominant species included mottled sculpin (20.8%), spottail shiner (16.2%), johnny darter (14.7%), and yellow perch (11.6%) (Table 16). Species which were at least twice as abundant in summer offshore samples as in nearshore samples included johnny darter and mottled sculpin. Brook stickleback, ninespine stickleback and northern pike occurred only at the offshore site. Conversely, species twice as abundant nearshore compared to offshore included spottail shiner and logperch. Additionally, 63% of yellow perch collected were taken at the nearshore site. Species occurring only at the nearshore site included emerald shiner and mimic shiner.

In Lake Munuscong, trout-perch dominated trawl samples during summer comprising 41.4% of the collections (Table 16). Spottail shiner and johnny darter were numerically important comprising 20.5% and 14.4% of the catch respectively. Three other species collectively comprised 17.3% of summer trawl collections: white sucker, mimic shiner and yellow perch. Johnny darter, trout-perch, and mimic shiner were at least twice as abundant at the offshore site as at the nearshore site. Rock bass and walleye were also in this category, but total numbers collected were less than 10 individuals for each species. Species

Table 16. Number of fish collected with a 4.9 meter (16') semi-baloon otter trawl during July and August, 1980, in the Middle Neebish Channel, St. Marys River.

	Course 7		Lake Munuscong			
Species	July	August	July	August	Total	
Rainbow smelt	0	18	28	4	50	
Northern pike	1	0	1	1	3	
Blacknose shiner	0	2	0	3	5	
Common shiner	0	0	4	0	4	
Emerald shiner	0	2	0	4	6	
Mimic shiner	0	36	0	74	110	
Sand shiner	0	7	0	2	9	
Spottail shiner	0	154	171	106	431	
White sucker	9	34	93	15	151	
Brown bullhead	0	0	1	0	1	
Brook stickleback	57	19	4	0	80	
Ninespine stickleback	3	50	6	1	60	
Trout-perch	36	36	106	453	631	
Rock bass	0	1	3	3	7	
Smallmouth bass	0	0	0	2	2	
Iowa darter	1	3	0	0	4	
Johnny darter	23	117	149	45	334	
Logperch	2	32	1	0	35	
Yellow perch	6	104	46	5	161	
Walleye	0	0	0	7	7	
Mottled sculpin	159	39	12	1	211	
Daily Total	297	654	625	726	2302	Seasonal Total
Number of species	10	16	14	16	21	

collected offshore but absent nearshore included northern pike, blacknose shiner, emerald shiner, sand shiner, brown bullhead, ninespine stickleback, rock bass, smallmouth bass and yellow perch. Two species, the logperch and common shiner, were collected at the nearshore site and not at the offshore site. No species were twice as abundant nearshore, although 59% of the spottail shiners were taken at this site.

Fall. A total of 1,170 fish representing 18 species were collected in 8 trawl samples during fall. Overall, johnny darter was most abundant comprising 31.6% of the catch (Table 17). Other numerically important species included mimic shiner (15.6%), rainbow smelt (11.2%), spottail shiner (8.7%), slimy sculpin (7.5%), mottled sculpin (6.7%), and trout-perch (5.6%).

At navigation course 7, 339 fish were taken at the nearshore site and 269 were collected offshore. Dominant species included johnny darter (35.4%), slimy sculpin (14.5%), mottled sculpin (12.2%), and rainbow smelt (12.0%) (Table 17). Spottail shiner, brook stickleback and ninespine stickleback collectively comprised 15.5% of the total catch. Johnny darter and logperch were more than twice as abundant in nearshore samples than in offshore samples. Blacknose shiner, sand shiner and walleye were collected only at the nearshore site. Brook stickleback and ninespine stickleback were more than twice as abundant offshore compared to nearshore sites. Northern pike and mimic shiner were taken only at the offshore site.

Trap Net

A total of 1,251 fish representing 26 species were taken with 16 shoreline trap net samples. Overall, brown bullhead was the most abundant species (19.9% of total catch). Differences in species compo-

Table 17. Number of fish collected with a 4.9 meter (16') semi-baloon otter trawl during September and October, 1980, in the Middle Neebish Channel, St. Marys River.

	Course 7		Lake Munuscong		
Species	September	October	September	October	Total
Cisco	0	0	1	1	2
Rainbow smelt	68	5	57	1	131
Northern pike	0	1	0	0	1
Blacknose shiner	0	0	0	1	1
Mimic shiner	6	4	0	172	182
Sand shiner	0	2	0	0	2
Spottail shiner	38	8	44	12	102
White sucker	9	6	5	1	21
Brook stickleback	16	7	0	29	52
Ninespine stickleback	22	3	2	0	27
Trout-perch	1	2	60	1	64
Rock bass	2	3	2	3	10
Johnny darter	134	81	109	46	370
Logperch	12	0	1	0	13
Yellow perch	8	6	1	9	24
Walleye	1	0	1	0	2
Mottled sculpin	13	61	0	4	78
Slimy sculpin	88	0	0	0	88
Daily Total	418	190	283	279	1170 Seasonal Total
Number Species	14	14	10	11	18

sition among sampling stations occurred and sand shiner (15.5%), bluegill (13.5%), yellow perch (12.3%), white sucker (10.4%) and blacknose shiner (10.5%) all could be considered numerically important in the shoreline habitat.

Navigation Course 7. Twenty species of fish were collected in trap net samples within emergent vegetation along the shoreline of course 7 (Table 18). Ten of these species were in the minnow family (Cyprinidae), which together comprised 63.3% of the collections. Of these minnows, sand shiner and blacknose shiner were the most abundant. Yellow perch were also common as were bluegill, rock bass and white sucker.

Lake Munuscong. Four trap net samples at the shoreline areas of Lake Munuscong captured 108 fish representing 12 species. Bluegill comprised over half (54.6%) of the total catch (Table 19). White sucker, rock bass, and yellow perch collectively made up an additional 34.4% of the catch. The total catch in October at this station was roughly one-tenth the total catch in September.

Lake Nicolet. Three habitat types were selected on the west shore of Lake Nicolet to study fish distribution in relation to cover type. Two trap net samples were collected in each of the heavy cover, medium cover and open areas. The heavy cover area was characterized by mixed emergent vegetation, little open water area and a flocculent organic substrate. The medium cover area was located in a bed of *Scirpus acutus* and *Scirpus americanus* with irregular openings in the emergent growth. Sampling was conducted in these openings. The open area contained no emergent vegetation.

Trap net samples from the three habitat types revealed substantial differences in fish utilization (Table 20). In the heavy cover zone,

Table 18. Number of fish collected with a small mesh trap net in navigation course 7, Middle Neebish Channel, St. Marys River, during 1980.

Species	August	September	October	Total	
Blackchin shiner	0	2	0	2	
Blacknose shiner	62	64	5	131	
Common shiner	8	13	3	24	
Emerald shiner	0	0	6	6	
Golden shiner	2	0	0	2	
Mimic shiner	2	2	1	5	
Sand shiner	20	150	24	194	
Spottail shiner	33	0	3	36	
Bluntnose minnow	18	1	0	19	
Lake chub	13	0	0	13	
White sucker	6	43	2	51	
Brown bullhead	0	12	1	13	
Brook stickleback	1	2	1	4	
Bluegill	16	40	4	60	
Rock bass	2	14	5	21	
Smallmouth bass	0	2	0	2	
Johnny darter	1	4	0	5	
Logperch	0	7	1	8	
Yellow perch	10	61	13	84	
Mottled sculpin	0	0	2	2	
Daily Total	194	417	71	682	Seasonal Total
Number Species	14	15	14	20	

Table 19. Number of fish collected with a small mesh trap net in Lake Munuscong, St. Marys River, during 1980.

Species	September	October	Total	
Carp	1	0	1	
Emerald shiner	1	0	1	
White sucker	15	0	15	
Brown bullhead	1	0	1	
Banded killifish	1	0	1	
Brook stickleback	0	1	1	
Trout-perch	1	0	1	
Bluegill	52	7	59	
Rock bass	14	1	15	
Johnny darter	2	0	2	
Yellow perch	6	1	7	
Mottled sculpin	4	0	4	
Daily Total	98	10	108	Seasonal Total
Number Species	11	4	12	

Table 20. Number of fish collected with a small mesh trap net during 8 - 15 October, 1980, in three separate habitat types of Lake Nicolet, St. Marys River.

Species	Cover Type				
	Heavy	Medium	Open	Total	
Central mudminnow	0	5	0	5	
Northern pike	0	0	1	1	
Common shiner	0	0	3	3	
Golden shiner	0	0	2	2	
Spottail shiner	0	3	5	8	
White sucker	28	28	8	64	
Brown bullhead	227	23	4	254	
Brook stickleback	0	1	0	1	
Ninespine stickleback	0	1	2	3	
Bluegill	3	34	13	50	
Rock bass	0	5	1	6	
Logperch	0	0	1	1	
Yellow perch	0	8	55	63	
Daily Total	258	108	95	461	Seasonal Total
Number Species	3	9	11	13	

brown bullhead comprised 88.0% of 258 fish collected. Two other species were collected in this area.

In the medium cover habitat, bluegill comprised 31.5% of the collection (Table 20). However, white sucker and brown bullhead were almost as abundant as bluegill. Six additional species were collected in the medium cover area.

In the open area, yellow perch were the most abundant species (57.9% of total catch). Ten other species were collected in the open area, but none was considered abundant.

Day and Night Comparisons. Pooled data from all 8 day and 8 night trap net samples revealed that roughly two-thirds of the fish were captured at night (Table 21). Of those species considered numerically abundant, brown bullhead and sand shiner were captured almost exclusively at night. White sucker and bluegill were also captured in greater numbers at night. Conversely blacknose shiner and yellow perch were captured in greater numbers during daylight hours.

Shoreline Seine

A total of 309 fish representing 20 species were collected in 5 shoreline seine samples in July and October. Emerald shiner, spottail shiner and trout-perch were the three most abundant species.

Spottail shiner comprised 54.8% of the total collection of 10 species during July (Table 22). Large ship-induced waves at course 7 during July sampling resulted in an aborted sample at this station.

Emerald shiner and trout-perch comprised 54.3% and 26.4% of the October seine collections respectively (Table 23). Most individuals of these two species were captured at course 5. None of the other 14

Table 21. Total number and percent of all species of fish collected during day and night trap net sampling in the St. Marys River during 1980.

Species	Day No.	Day %	Night No.	Night %
Central mudminnow	0	0	5	100
Northern pike	0	0	1	100
Carp	0	0	1	100
Blackchin shiner	2	100	0	0
Blacknose shiner	105	80	26	20
Common shiner	13	48	14	52
Emerald shiner	0		7	100
Golden shiner	3	75	1	25
Mimic shiner	4	80	1	20
Sand shiner	5	3	189	97
Spottail shiner	37	84	7	16
Bluntnose minnow	18	95	1	5
Lake chub	13	100	0	0
White sucker	57	44	73	56
Brown bullhead	10	4	258	96
Banded killifish	0	0	1	100
Brook stickleback	3	50	3	50
Ninespine stickleback	2	67	1	33
Trout-perch	0	0	1	100
Bluegill	64	38	105	62
Rock bass	4	10	38	90
Smallmouth bass	1	50	1	50
Johnny darter	3	43	4	57
Logperch	7	78	2	22
Yellow perch	105	68	49	32
Mottled sculpin	2	33	4	67
Total	458	37	793	63
Number of species	21		24	

Table 22. Number of fish collected with a 61 meter (200') beach seine during 29 July, 1980, in the Middle and West Neebish Channel, St. Marys River.

Species	Station 5	Station 9	Total
Common shiner	9	0	9
Mimic shiner	3	3	6
Spottail shiner	48	15	63
Blacknose dace	1	0	1
Silver redhorse	3	0	3
Trout-perch	1	5	6
Rock bass	10	0	10
Johnny darter	0	1	1
Walleye	8	0	8
Yellow perch	0	5	5
Daily Total	83	29	112 Seasonal Total
Number Species	8	5	10

Table 23. Number of fish collected with a 61 meter (200') beach seine on 1 October, 1980, in the Middle and West Neebish Channels, St. Marys River.

Species	Station 5	7	9	Total	
Rainbow smelt	0	0	1	1	
Blacknose shiner	0	2	0	2	
Common shiner	1	5	0	6	
Emerald shiner	106	1	0	107	
Mimic shiner	2	1	0	3	
Rosycheek shiner	2	0	0	2	
Sand shiner	1	2	0	3	
Spottail shiner	0	0	1	1	
Lake chub	0	0	7	7	
Longnose dace	0	2	1	3	
White sucker	1	0	0	1	
Trout-perch	47	5	0	52	
Johnny darter	0	1	5	6	
Logperch	1	0	0	1	
Walleye	1	0	0	1	
Slimy sculpin	0	1	0	1	
Daily Total	162	20	15	197	Seasonal Total
Number Species	9	9	5	16	

species collected during October were represented by more than 7 individuals.

Length Frequency of Common Species

Cisco. Cisco were collected almost exclusively in gill nets. Only two individuals were taken with other gear. This species ranged from 103 mm to 454 mm in total length (TL) with peaks of frequencies centered about the 115, 235, 295, and 385 mm intervals (Table 24).

Immature cisco collected during winter ranged from 230 mm to 327 mm TL ($\bar{x}$ = 274.1 mm). No immature cisco were collected during summer. Immature cisco collected during fall ranged from 103 mm to 254 mm TL ($\bar{x}$ = 141.6 mm). All fish less than 160 mm were collected in or near emergent vegetation along shore. Horizontal distribution patterns of other sizes or sexes were not apparent.

Mean total lengths and ranges of female cisco from winter, summer and fall were 369.6 mm (259-443 mm), 364.9 mm (248-423 mm) and 338.7 mm (217-454 mm) respectively. Male cisco averaged slightly less than females with mean total length in winter, summer and fall being 358.9 mm (261-417 mm), 362.7 mm (277-384 mm) and 316.4 mm (212-407 mm) respectively.

Northern Pike. Northern pike were sampled mainly by gill nets with an occasional individual collected with bottom trawl or trap net. This species ranged from 185 mm to 904 mm TL. Forty-nine percent of the northern pike were within 460-580 mm TL (Table 25).

Three immature northern pike (383-435 mm) were collected during summer. Female northern pike were more common than males and were also larger. Mean total lengths of females collected during winter, summer and fall were 582.0 mm (range 396-760 mm), 527.3 mm (462-583 mm)

Table 24. Length frequency table for cisco collected from the Middle Neebish Channel, St. Marys River with gill nets during 1980.

Mid-point of length interval (mm)	Female	Male	Immature	sex Undetermined	Total
100			3		3
115			6		6
130			3		3
145			1		1
160					
175					
190					
205					
220	4	2			6
235	2	4	5		11
250	2	2	1	1	6
265	3	3	4		10
280	6	4		3	13
295	8	9	1	6	24
310	10	11		1	22
325	3	4	3	1	11
340	5	2		1	8
355	7	5		3	15
370	15	5		4	24
385	25	14		1	40
400	18	16			34
415	13	4		3	20
430	2	1			3
445	2				2
460	1			1	2
	126	86	27	25	264

Table 25. Length frequency table for northern pike collected from the Middle Neebish Channel, St. Marys River with gill nets during 1980.

Mid point of length interval (mm)	Female	Male	Immature	sex Undetermined	Total
185		1			1
320				1	1
360					
400	1	2	2	6	11
440	1	2	1	5	9
480	2	5		7	14
520	9	4		5	18
560	5	3		6	14
600	1			4	5
640	6			2	8
680	1			6	7
720				2	2
760	1				1
800					
840	1				1
880					
920	1				1
	29	17	3	44	93

and 674.6 mm (457-904 mm) respectively. One male northern pike collected in winter was 526 mm. During summer male northern pike averaged 490.7 mm (416-558 mm) and during fall 452.1 mm (185-577 mm). Sex was not determined for a large proportion of the northern pike released alive.

During winter only one male northern pike was collected compared to 18 females. During summer and fall, females comprised 43% and males 57% of the adult fish.

White Sucker. White suckers were common in gill net, trawl and trap net collections. The majority (85%) of white suckers collected with gill nets were mature fish. Conversely, the majority (80%) of white suckers collected with the trawl and trap net were immature.

Young-of-the-year (YOY) white suckers 16-115 mm were often abundant in trawl or trap net collections and comprised 44% of the total catch (Table 26). Average length of YOY white sucker in summer trawl samples was 47.6 mm. During fall average length of YOY white suckers collected with trawls and trap nets was 57.5 mm and 62.2 mm respectively. Immature fish 130-285 mm were not collected with the trap net, but were present in trawl and gill net samples. Mean total length of immature white sucker collected with gill nets was 256.5 mm (238-275 mm) in winter, 274.0 mm (259-288 mm) in summer and 292.7 mm (231-346 mm) during fall.

Adult white suckers ranged from 270 mm to 700 mm TL. Average lengths of females during winter, summer and fall were 437.9 mm (402-480 mm), 440.4 mm (360-512 mm) and 414.5 (270-483 mm). Males averaged slightly smaller in each season with mean total lengths in winter (1 fish), summer and fall being 430 mm, 396.9 mm (338-454 mm) and 388.2 mm (236-420 mm) respectively.

Table 26. Length frequency table for white sucker collected in the St. Marys River with gill nets, trawls and trap nets during 1980.

Mid-point of length interval (mm)	Gill Net				Trawl		Trap Net		
	Female	Male	Immature	Undetermined	Sex Undetermined	Immature	Sex Undetermined	Immature	Total
30						52		8	60
60						21		70	91
90						3		15	18
120						5		1	6
150						1			1
180						5			5
210					1	3			4
240		1	3	1		3			8
270	2	1	4						7
300			2	3		1	3		9
330		2	2	4	3	1	1		13
360	1	3	1	6	4		3		18
390	4	4		11	1		1		21
420	17	10		29	4		14		74
450	13	3		15			8		39
480	5			3			3		11
510				1			1		2
700				1					1
	42	24	12	74	13	95	34	94	388

Females dominated white sucker catches during winter comprising 17 of 20 fish collected. During summer and fall females comprised 58% of the adult fish examined for sex determination. Many adult fish that were gill netted were released alive as were all adult individuals caught in other gear. The released fish were not included in the sex ratio calculation.

Yellow Perch. Yellow perch were also common in gill net, trawl and trap net samples. Gill net catches were comprised mostly of mature perch (94%), trawl catches were made up of 28% mature and 72% immature fish, while 99.4% of perch from trap nets were immature.

Immature yellow perch collected with summer trawls averaged 62.4 mm (33-119 mm) total length and during fall 57.9 mm (35-76 mm). Immature fish at the 50 mm interval and smaller comprised over half of the immature yellow perch collected and were likely YOY fish (Table 27).

Female yellow perch from gill nets averaged 222.0 mm (170-275 mm), 203.9 mm (87-251 mm) and 228.8 mm (173-305 mm) in winter, summer, and fall samples respectively. No male yellow perch were collected during winter. During summer, males averaged 222.2 mm (134-316 mm) and during fall, 211.4 mm (102-339 mm).

Brown Bullhead. Brown bullheads were common in gill net collections from Lake Munuscong, abundant in trap net samples from heavy cover, and common in trap net samples from medium cover. Few were taken with other gear. This species was not collected during winter.

Immature brown bullheads 44-90 mm ($\bar{x}$ = 57.7) total length comprised 76% of trap net collections (Table 28). Nine immature individuals 139-200 mm were also collected (2 from gill nets, 7 from trap nets).

Female brown bullheads from trap nets ranged from 171 mm to 190 mm

Table 27. Length frequency table for yellow perch collected in the St. Marys River with gill nets, trawls, and trap nets during 1980.

Mid point of length interval (mm)	Gill Net				Trawl			Trap Net		
	Female	Male	Immature	sex undetermined	Female	Male	Immature	Male	Immature	Total
30							6		4	10
50							29		87	116
70							12		72	84
90	1		2			1	3			7
110	1	1		1	1	2	4			10
130		1			1	4	2			8
150		1				4				5
170	5	2	1	2	1	2		1		14
190	9	5	2	4	1					21
210	13	8	1	4						26
230	13	5		7	1					26
250	10	2		4	2					18
270	4	2		8						14
290	1			3	2					6
310	1	2		2						5
330		1		2						3
	58	30	6	37	9	13	56	1	163	373

Table 28. Length frequency table for brown bullhead collected in the St. Marys River with gill nets and trap nets during 1980.

Mid point of length interval (mm)	Gill Net				Trap Net				Total
	Female	Male	Immature	Sex undetermined	Female	Male	Immature	Sex undetermined	
50							44		44
70							19		19
90							1		1
110									
130			1						1
150			1						1
170					2	1	3	1	7
190				1	1	2	4	1	9
210						1			1
230									
250								4	4
270	1	2		1				3	7
290	2	2				1		2	7
310		1						2	3
330	1	1		11					13
	4	6	2	13	3	5	71	13	117

total length while females collected with gill nets were larger (270-330 mm). Male brown bullheads collected with trap nets (172-290 mm) were also smaller than males collected with gill nets (270-322 mm).

Trout-perch. Trout-perch were the second most abundant species collected by trawling and were common in seine collections along open shoreline areas. Trout-perch were occasionally collected in the 1-inch mesh gill net and one individual was collected with the trap net.

Immature trout-perch collected during summer ranged in total length from 18 mm to 60 mm ($\bar{x}$ = 32.2 mm). During fall, immature individuals ranged from 23 mm to 37 mm ($\bar{x}$ = 30.1 mm). Of all fish sexed, immature fish comprised 45% of trout-perch from trawls and 25% of trout-perch from seine samples (Table 29).

Mature fish caught during summer were larger than those taken during fall. Female trout-perch from trawls averaged 71.9 mm (46-100 mm) total length during summer and 59.7 mm (48-87 mm) during fall. Male trout-perch from summer trawls were similar in total length to females ($\bar{x}$ = 71.8 mm) but exhibited a wider length range (43-113 mm). During fall, male trout-perch were smaller than females ($\bar{x}$ = 53.5 mm, range 37-70 mm).

Spottail Shiner. Spottail shiners were collected by all gear types. This species was common in trawl samples and often common in seine or trap net samples. Occasional individuals were collected with gill nets. Lengths and sex composition were determined mainly from trawl samples.

Nearly one third (29%) of the spottails from summer and fall trawls were immature. Immature spottails from summer trawls averaged 44.7 mm (31-63 mm) total length and from fall trawls, 35.3 mm (22-48 mm) (Table 30).

Table 29. Length frequency table for trout-perch collected in the St. Marys River with bottom trawls and shoreline seines during 1980.

Mid-point of length interval (mm)	Trawl			Seine				Total
	Female	Male	Immature	Female	Male	Immature	Sex undetermined	
15			1					1
25			19					19
35		1	38					39
45	2	4	1	1		1		9
55	2	2	1	5	2	5	10	27
65	9	10	1	4	3		3	30
75	17	18						35
85	1	4		2				7
95	1	2			1			4
105	1	1						2
115		1						1
	33	43	61	12	6	6	13	174

Table 30. Length frequency table for spottail shiners collected in the St. Marys River with bottom trawls during 1980.

Mid point of length interval (mm)	Female	Male	Immature	Total
20			1	1
25		1	3	4
30		1	2	3
35	4	6	13	23
40	2	2	10	14
45	1	3	3	7
50	2		2	4
55	1	3	2	6
60	4	8	3	15
65	3	5	1	9
70	5	4		9
75	5	4		9
80	6	5		11
85	8	2		10
90	6	3		9
95	1			1
100	2			2
105	1			1
110	1			1
	52	47	40	139

Among adults, 53% were female, 47% male. Mature spottails collected during summer were larger than mature individuals from fall. Female spottails averaged 77.6 mm (43-108 mm) total length from summer trawls adn 44.0 mm (34-84 mm) in fall trawls. Likewise, males averaged 69.6 mm (56-90 mm) during summer and 48.1 mm (25-90) during fall.

Johnny Darter. Johnny darter was the most abundant species in trawl samples. An occasional johnny darter was also collected among the shoreline in trap nets or seines (14 individuals). None were collected in gill nets.

Immature johnny darters comprised 28% of all individuals. Male johnny darter comprised 63% of all adult fish (females 37%). This ratio was similar during both summer and fall.

Immature johnny darters averaged 24.3 mm (18-25 mm) total length in summer and 30.4 mm (22-44 mm) in fall. Female darters averaged 43.1 mm (28-56 mm) in summer and 46.7 mm (37-60 mm) during fall while males averaged 42.8 mm (34-59 mm) during summer and 47.2 mm (32-58 mm) during fall. The majority of fish were in the 40-50 mm length intervals (Table 31).

Food Habits

Cisco. Eighty-four cisco stomachs were examined from fish collected in the Middle Neebish Channel during winter (50 fish), and, during summer and fall (34 fish). Eighteen fish (21%) had empty stomachs. During winter, copepods comprised the bulk of the cisco diet both numerically and volumetrically (Table 32). However, cisco also fed upon other invertebrates, particularly nymphs of the mayfly family, Leptophlebiidae. Four stomachs each contained more than 100 Leptophlebiidae nymphs.

Table 31. Length frequency table of johnny darters collected in the St. Marys River with bottom trawls during 1980.

Mid point of length interval (mm)	Female	Male	Immature	Total
20			4	4
25			21	21
30	1	1	17	19
35	6	16	7	29
40	11	18	1	30
45	13	16	1	30
50	14	20		34
55	2	8		10
60	1	2		3
	48	81	51	180

The cisco diet was more varied during summer and fall. Copepods continued to be the most numerous food item. However, copepods did not occur in stomachs as frequently nor were they as important volumetrically as in winter (Table 33). Insects or insect parts were found in 76% of summer and fall stomachs. The most abundant insects were mayflies of the family Ephemeridae (Table 33). These organisms (adult and nymph) comprised over 60% of the volume of summer and fall food items.

Northern Pike. Fifty-two northern pike stomachs were examined for food habit analysis (19 from winter, 33 from summer and fall). Fish dominated the food items during both winter and open water periods (Tables 34 and 35). Eight of nineteen fish (42%) examined during winter had empty stomachs. Most other stomachs contained one food item.

During summer and fall, fish occurred in all stomachs and more than one food item was found in 19 of 29 stomachs containing food. Numerically, unidentified fish (partially digested) were the most common item followed by ninespine stickleback. This result was strongly influenced by one stomach which contained 25 ninespine sticklebacks. Volumetrically, rainbow smelt were the most important food item of summer and fall northern pike, while unidentified fish were second.

Walleye. Sixty-four walleye collected in the Middle Neebish Channel were examined for food habits including 13 from winter and 51 from summer/fall. Most winter stomachs were empty (8), 2 contained a single fish, and 4 contained leeches (12 leeches total)(Table 36).

All stomachs from summer/fall walleyes contained food. Fish were the major food item for both immature and mature walleye (Table 37). Larval fish occurred in over half of immature walleye stomachs, but

Table 32. Summary of food habits of immature and mature cisco collected from the St. Marys River during periods of ice cover (winter).

Food Item	Percent Total Number	Percent Volume	Percent Frequency of Occurrence
Crustacea	88.3	75.0	95.1
Copepoda (Calanoida)	88.3	75.0	82.9
Copepoda parts	-*	-	12.2
Insecta	11.7	23.5	24.4
Ephemeroptera			
Leptophlebiidae	11.7	23.4	19.5
Ephemeroptera parts	-	-	2.4
Corixidae	-	0.1	2.4
Fish	-	1.5	2.4
Unidentified fish	-	1.5	2.4
n	41		
Number empty stomachs	9		

*a dash (-) indicates less than 0.1

Table 33. Summary of food habits of immature and mature cisco collected from the St. Marys River during periods of open water.

Food Item	Percent Total Number	Percent Volume	Percent Frequency of Occurrence
Crustacea	83.2	20.7	40.0
Copepoda (Calanoida)	81.9	16.9	32.0
Cladocera	1.3	2.6	4.0
Isopoda	-*	1.2	4.0
Insecta	16.6	67.5	76.0
Ephemeroptera			
Ephemeridae adult	14.7	56.2	36.0
Ephemeridae nymph	0.7	7.4	32.0
Unidentified nymph	-	0.3	4.0
Odonata pupae	0.1	2.9	4.0
Diptera			
Chironomidae pupae	0.9	0.5	20.0
Insect parts	0.2	0.2	12.0
Fish	-	1.5	4.0
Unidentified fish	-	1.5	4.0
Plant			
Aquatic macrophyte	-	-	4.0
Miscellaneous & Unidentified	0.2	10.2	12.0
n	25		
Number empty stomachs	9		

*a dash (-) indicates less than 0.1

Table 34. Summary of food habits of immature and mature northern pike collected from the St. Marys River during periods of ice cover (winter).

Food Item	Percent Total Number	Percent Volume	Percent Frequency of Occurrence
Fish	82.5	98.8	81.8
Percidae (Yellow perch)	5.9	35.3	9.1
Percidae (Johnny darter)	5.9	0.5	9.1
Percopsidae (Trout-perch)	5.9	12.8	9.1
Osmeridae (Rainbow smelt)	11.8	34.2	9.1
Cottidae (Sculpin)	5.9	5.3	9.1
Unidentified fish	11.8	7.5	9.1
Fish parts	35.3	3.2	54.6
Invertebrate	5.9	0.5	9.1
Decapoda	5.9	0.5	
Unidentified material	11.8	0.6	18.2
n	11		
Number empty stomachs	8		

Table 35. Summary of food habits of immature and mature northern pike collected from the St. Marys River during periods of open water.

Food Item	Percent Total Number	Percent Volume	Percent Frequency of Occurrence
Fish	98.0	99.9	100
Osmeridae (Rainbow smelt)	8.4	30.8	24.1
Gasterosteidae (Brook stickleback)	12.1	3.7	10.3
Gasterosteidae (Ninespine stickleback)	23.4	9.2	3.5
Cottidae (Sculpin)	6.5	13.4	13.8
Percidae (Johnny darter)	2.8	0.4	3.5
Percopsidae (Trout-perch)	0.9	6.5	3.5
Unidentified fish	30.8	27.9	51.7
Fish parts	14.1	8.0	37.9
Insecta	1.9	-*	3.5
Ephemeroptera	1.9	-	3.5
n	29		
Number empty stomachs	4		

* a dash (-) indicates less than 0.1.

Table 36. Summary of food habits of immature and mature walleye collected from the St. Marys River during periods of ice cover (winter).

Food Item	Percent Total Number	Percent Volume	Percent Frequency of Occurrence
Fish	14.3	28.6	40.0
Unidentified fish	14.3	28.6	40.0
Invertebrate	85.7	71.4	80.0
Hirudinea	85.7	71.4	80.0
n	5		
Number empty stomachs	8		

Table 37. Summary of food habits of immature and mature walleye collected from the St. Marys River during open water periods.

Food Item	Immature (123 - 330 mm TL)			Mature (345 - 516 mm TL)		
	Percent Total Number	Percent Volume	Percent Frequency of Occurrence	Percent Total Number	Percent Volume	Percent Frequency of Occurrence
Fish	71.25	99.1	94.6	81.4	99.5	86.7
Osmeridae (Rainbow smelt)	1.25	25.5	2.7	35.2	75.4	53.3
Gasterosteidae (Stickleback)	1.25	0.7	2.7	1.8	0.3	6.7
Cottidae (Sculpin)	0.0	0.0	0.0	1.8	2.4	6.7
Unidentified adult fish	22.5	56.6	35.1	33.3	19.0	46.7
Unidentified larval fish	42.5	1.9	51.4	0.0	0.0	0.0
Fish parts	3.75	14.4	8.1	9.3	2.4	7.4
Invertebrates	27.5	0.9	10.8	16.6	0.4	40.0
Diptera	2.5	-*	5.4	0.0	0.0	0.0
Ephemeroptera	1.25	-	2.7	1.8	0.1	6.7
Unidentified insect	6.25	0.2	5.4	3.7	0.1	13.3
Hirudinea	17.5	0.7	13.5	9.3	0.1	20.0
Decapoda	0.0	0.0		1.8	0.1	6.7
Unidentified Material	1.25	-	2.7	2.0	-	6.7
n	15			36		

* a dash (-) indicates less than 0.1.

were absent in mature walleye. Rainbow smelt and unidentified fish were the most important food items for mature walleye both numerically and volumetrically. Leeches (Hirudinea) were also common in summer and fall walleye stomachs (Table 37).

Yellow Perch. One hundred and thirty-seven yellow perch collected from the Middle Neebish Channel were examined for food habits (12 winter, 125 open water). The major food items during winter were mayfly nymphs. One fish was found in the 9 stomachs and accounted for most of the volume (Table 38).

Numerically important food items during open water seasons included Corixidae, Cladocera and Amphipoda (Table 39). Insects and crustaceans each comprised nearly half of the total food items. Volumetrically, fish (particularly johnny darter), mayflies, corixids, crayfish and amphipods were important food items.

DISCUSSION

Selectivity of Gear

Most fishing gears are selective and not representative of the population as a whole. Gear selectivity is the result of a variety of factors including gear construction, method of operation, behavioral differences among species or within species according to sex, size, season, etc. or a combination of the above (Lagler, 1968).

Gill nets are passive fishing gear which depend upon fish movement. Catch per effort is a function of activity of fish as well as abundance (Carlander, 1953). Fish activity is influenced by temperature and during cold periods fish can be expected to move less than during warmer periods. However, recent evidence suggests that at least some

Table 38. Summary of food habits of mature yellow perch collected from the St. Marys River during periods of ice cover (winter).

Food Item	Percent Total Number	Percent Volume	Percent Frequency of Occurrence
Insecta	83.3	27.5	88.9
Ephemeroptera			
Ephemeridae	70.8	26.4	66.7
Unidentified nymph	8.3	0.8	22.2
Unidentified insect	4.2	0.3	11.1
Fish	4.2	72.3	11.1
Unidentified fish	4.2	72.3	11.1
Plant	4.2	-*	11.1
Aquatic macrophyte	4.2	-	11.1
Unidentified material	8.3	0.2	22.2
n	9		
Number empty stomachs	3		

*a dash (-) indicates less than 0.1

Table 39. Summary of food habits of immature and mature yellow perch collected from the St. Marys River during periods of open water.

Food Item	Percent Total Number	Percent Volume	Percent Frequency of Occurrence
Insecta	51.8	46.8	78.2
Hemiptera (Corixidae)	37.8	16.0	41.2
Ephemeroptera			
Ephemeridae	3.6	18.3	24.4
Unidentified nymph	3.3	5.3	28.6
Coleoptera			
Dytisidae	1.0	1.4	10.9
Unidentified larvae	1.7	2.5	7.6
Diptera			
Chironomidae larvae	0.9	0.2	10.9
Chironomidae pupae	-*	-	0.8
Chironomidae adult	0.3	0.1	4.2
Odonata	0.4	0.2	6.7
Lepidoptera	1.1	0.2	1.7
Trichoptera			
Hydropsychidae	-	-	0.8
Unidentified larvae	0.6	0.7	2.5
Homoptera	-	-	0.8
Plecoptera	-	-	0.8
Collembola	-	-	0.8
Insect parts (unidentified)	0.8	1.6	10.1
Crustacea	47.0	24.0	63.9
Amphipoda	7.7	5.5	31.1
Isopoda	1.2	3.9	4.2
Decapoda	0.4	11.3	7.6
Ostracoda	-	-	0.8
Cladocera	31.7	3.2	46.2
Copepoda	6.0	0.1	6.7

Table 39. continued

Food Item	Percent Total Number	Percent Volume	Percent Frequency of Occurrence
Fish	1.0	28.6	9.2
Percidae (Johnny darter)	0.6	23.7	5.0
Cottidae (Sculpin)	0.1	0.3	0.8
Fish parts	0.3	4.6	4.2
Plant	-	0.3	3.4
Algae	-	-	1.7
Aquatic macrophytes	-	0.3	1.7
Unidentified & Miscellaneous (Stickleback)	-	0.2	1.6
n	122		
Number empty stomachs	3		

*a dash (-) indicates less than 0.1

species exhibit similar daily movement patterns during winter and summer in temperate latitudes (Diana et al., 1977). Size and morphology of fish also influence gill net catches. Heavily-toothed species (northern pike), fish with ctenoid scales (yellow perch, walleye) and fish with spinous rays (carp, bullhead) are more susceptible to gill nets (Jude et al., 1975).

Trawls are active fishing gear which theoretically capture all fish within a specific area above a given size. However, Jude et al. (1975) employed a trawl in Lake Michigan of similar size to the trawl used in this study and stated it was inefficient in capturing large fish. Our observations support his statement.

Beach seines are also active fishing gear employed along the shoreline. This habitat is probably the most variable in an aquatic system and problems arise in replicating methods when currents or wave action varies among samples. Little habitat suitable for shoreline seining exists in the St. Marys River as the majority of the river's edge supports emergent vegetation.

Trap nets are passive fishing gears and like gill nets are dependant upon activity of fish. Trap net catches are influenced by mesh size, physical dimensions of the net (opening to pot, length of lead, etc.) and the habitat fished. We employed trap nets primarily in vegetated littoral areas because other methods had proven unsuccessful in this habitat. Catches were predominated by small fish, but several large fish were captured including 30 adult white suckers on one date.

One method of comparing gear selectivity is to compare length frequency distributions of catches from different gear (Lagler, 1968).

This was done for species commonly collected by two or more methods. For species such as white sucker and yellow perch, gill nets are clearly more efficient in capturing larger fish, while trawls and trap nets are more efficient in capturing small individuals.

We selected gill nets as our primary sampling gear because of comparability of this data with earlier data. Another consideration was the selection of a primary sampling gear which could be employed under ice with relative ease. Other methods (trawls, trap nets and seines) were employed to augment gill netting. Although replication of these methods is not as frequent as gill netting, the data obtained is valuable in understanding the fish population under study.

Habitat

A primary goal of the 1980 sampling program was to determine horizontal fish distribution in a lake and narrow channel habitat of the St. Marys River. In the course of sampling it became apparent that at least three subhabitats existed within each of these larger areas as one proceeded from the shoreline out to the shipping lanes. We have classified these three habitats as deep water (adjacent the shipping channel), shallow water and shoreline.

The deep water habitat consisted of that area adjacent the shipping channel and shoreward approximately 250 m (820'). The deep water habitat has depths of 6 - 7 m (20 - 23') along the shipping channel and about 3 m (10') on the shoreward boundary. The shallow water habitat consisted of that area between the deep water and the appearance of emergent vegetation. Depths in the shallow water habitat were 3.0 - 3.5 m (10 - 11.5'). The shoreline habitat consisted of the area beginning at the water's edge and proceeded out to a depth of about 1.5 m (5'). This

habitat typically supports emergent aquatic vegetation on the leeward side of the Middle Neebish Channel. Exceptions exist, such as docks or other structures which have been built.

The fish community of the deep and shallow water habitat are similar. Seasonal and diurnal shifts from one depth to another were noted, however. Species most characteristic of these habitats include cisco, rainbow smelt, northern pike, mimic and spottail shiner, white sucker, brook and ninespine stickleback, adult brown bullhead, trout-perch, rock bass, johnny darter, yellow perch, walleye, mottled and slimy sculpin. An additional 18 species were collected from these two habitats.

The fish community inhabiting the shoreline habitat was different. This community included blacknose shiner, emerald shiner, sand shiner, spottail shiner, trout-perch and immature individuals of the following species: white sucker, brown bullhead, bluegill, rock bass and yellow perch.

Common Species

Cisco. Cisco were the predominant species collected with gill nets comprising 40% of the winter, 18.9% of the summer and 33.4% of the fall catch. The catch per unit effort was greater in 1980 than in 1979 for both under ice (CPE 1.4) and open water (CPE 6.6) sampling. Only 2 cisco were collected in gear other than gill nets.

During winter 56 cisco were captured with gill nets, 28 at course 7 and 28 in Lake Munuscong. At navigation course 7, cisco were most abundant at the shallow water site (26 of 28 fish) while in Lake Munuscong the opposite was true as 25 of the 28 fish collected were captured in deep water. During summer, only one individual was collected in Lake Munuscong. Although 92 cisco were collected at course 7 no apparent

pattern of horizontal distribution emerged. On 23 June, 32 of 38 cisco captured were taken in shallow water while on 15 July, 47 of 53 cisco were taken in deep water. During fall, cisco were common at both sampling stations and at both depth zones.

Offshore/onshore migration of cisco has been reported as well as vertical migration in deeper bodies of water (Engle and Magnuson, 1976; Dryer and Beil, 1964). In Pallette Lake, Wisconsin, Engle and Magnuson (1976) found that cisco nearshore in spring migrated offshore in May and remained there until fall when they moved inshore once again.

The distribution of cisco observed in the St. Marys River is likely influenced by food availability and water temperature. The shallow water site sampled in Lake Munuscong contained few plants whereas the offshore nets often contained charophytes when pulled. The opposite was true at navigation course 7. These macrophytes probably provide cover for invertebrates and attract feeding cisco. During summer, temperature may influence distribution. No cisco were collected in the nearshore habitat (0.0 - 1.5 m) (0-5'). Colby and Brooke (1969) suggest that 20°C is the upper thermal limit of mature cisco. Water temperatures alongshore often exceeded 20°C during summer. The upper thermal limit for young of the year cisco was later determined at 26°C by Edsall and Colby (1970).

Cisco captured in the St. Marys River ranged from 103 to 454 mm total length. Females were more numerous and larger than males during all seasons. Cisco collected in the St. Marys River attained larger maximum size than reported for Lake Superior (Dryer and Beil, 1964), Pallette Lake, Wisconsin (Engle, 1976), and other North American lakes summarized by Scott and Crossman (1973).

Diet of the cisco in the St. Marys River was predominantly copepods both numerically and volumetrically during winter. During summer copepods were also the most abundant food item. However, insects (mainly mayfly adults) comprised 67.5% of the volume of cisco food in summer.

Janssens (1978) observed that cisco (*C. artedii* and *C. hoyi*) do not filter feed, but gulp particles and are capable of feeding on the bottom. This would imply an ability to select larger food items. However, Engle (1976) found a predominance of small zooplankton in cisco stomachs and no evidence of size selection. Results of our cisco diet analysis indicate that cisco clearly feed on emerging Ephemeridae mayflies during July and probably gain considerable energy at this time.

Northern pike. Northern pike were more common in gill net catches comprising 15.0% of winter, 6.9% of summer and 10.7% of fall collections. Other sampling methods captured occasional individuals. Catch per effort during winter, summer and fall was 0.4, 2.4 and 1.7 respectively.

During winter most northern pike were collected from shallow water at course 7 and deep water in Lake Munuscong. During summer abundance was greater in deep water at both stations; in fall, fish appeared more evenly distributed. None of the differences in distribution proved to be significant.

Studies of northern pike movement in Lac Ste. Anne, Alberta, by Diana et al. (1977) indicated that no home range was established and that movement patterns were random about the lake in water of 4 m (13') depth or less and about 300 m (990') from shore. Similar movement of northern pike was noted by Moen and Henegar (1971).

Information from tag returns of northern pike tagged in the St. Marys River during 1979 seem to be in disagreement with the above

authors (Michigan State University, unpublished). Tag returns from sportsmen revealed that during most seasons northern pike were inhabiting the same area in which they were released up to 14 months earlier. Exceptions occur during spring. Several tag returns from the mouth of the Charlotte River suggest northern pike may feed in this area after spawning.

Northern pike captured in the St. Marys River ranged from 185 to 904 mm total length. Females outnumbered males 17:1 during winter, but similar numbers of each sex were collected during summer and fall. Females averaged larger than males during all seasons. Female pike exhibited modes in length distribution at the 520 and 640 mm intervals while males exhibited one mode at the 480 mm interval. Previous investigators in the St. Marys River found that pike of 20 inches (508 mm) were 5 years old (Wright and Schorffaar, 1976).

Analysis of northern pike stomachs indicated a similar diet during both winter and open water periods. However, volumes consumed were lower and a greater proportion of empty stomachs were found during winter. Northern pike food intake is highest from May to August and lowest during winter except for a fast during spawning (Diana, 1979). Low levels of food intake observed during winter (Keast, 1968; Diana and Mackey, 1979) are apparently sufficient for continued growth during periods of low water temperature (Diana and Mackay, 1979). The above authors suggest that the fish in northern latitudes which spend as much as half their life in water of approximately 1°C may have adapted mechanisms for continued growth over winter.

White Sucker. White suckers were common in all habitat types sampled. White suckers comprised 22.0% of gillnet, 10.4% of trap net

and 5.0% of trawl samples during all seasons combined. Catch per effort from gill net collections was lowest in winter (CPE 0.5), greatest in summer (CPE 8.9) and decreased again during fall (CPE 4.1). Two hundred seventeen white suckers were captured in gill nets, 172 in trawls, 130 in trap nets and 1 in shoreline seines.

During winter, 16 white suckers were captured at course 7 and 4 were captured in Lake Munuscong. No difference in horizontal distribution was apparent.

During summer, 74 fish were collected in deep water and 50 in shallow water with gill nets. Slightly more white suckers were taken in Lake Munuscong gill net sets than course 7 gill net sets during summer. Summer trawling captured 85 white suckers in deep water and 66 in shallow water. White suckers were approximately two and one-half times as abundant in trawl samples from Lake Munuscong as from course 7 during summer.

During fall gill netting, 45 white suckers were collected with shallow gill nets and 28 with deep gill nets. Collections among course 7 and Lake Munuscong were comparable. Trawls during fall captured only 21 white suckers and no distributional pattern could be discerned. Trap nets deployed in the shallow alongshore habitat captured 130 white suckers. Greatest trap net catches were recorded in navigation courses 7 and 5.

White suckers are common inhabitants of shallow water, nearshore environments in the Great Lakes (Lawrie, 1978; Galloway and Kevern, 1976). However, marked horizontal distribution within these shallow waters has not been reported to our knowledge and does not appear to be

the case in the St. Marys River. Kavaliers (1980) reported that shoals of white suckers disperse and move toward the shoreline at night, as well as dawn and dusk, to engage in feeding.

White suckers collected in the St. Marys River ranged from 22 to 700 mm in total length. Females outnumbered males 16:1 during winter, but similar numbers of each sex were collected during periods of open water. Females also average slightly larger than males during all seasons. The preponderance of females collected during winter suggests that males may congregate near spawning sites earlier than previous investigators (Galloway and Kevern, 1976) have determined.

Analysis of length frequency data for white suckers reveals the selectivity of gear types. Gill nets collected mostly larger fish, while trawls and trap nets collected smaller fish. Catch records of various sizes of white suckers indicate adult fish utilize all three habitats as suggested by Kavaliers (1980). However, juvenile white suckers appear to segregate, at least minimally. Trap nets captured what were likely young of the year fish (Galloway and Kevern, 1976) and fish of the 300 mm interval and larger, while trawls collected juvenile fish from the 30 to 240 mm interval in addition to larger fish. Assuming that gear bias is not a factor, this suggests that juvenile white suckers older than young-of-the-year leave the nearshore vegetated areas and move to open water. As approximately one fourth of white suckers taken in trap nets were 300 mm or larger it does not seem likely that trap nets are selective against fish 150-270 mm.

These data suggest white suckers are common in the St. Marys River throughout the year and may play an important role in energy transfer among trophic levels. However, none of the piscivorous fish stomachs

examined during this study positively contained white sucker. It should be noted that on two occasions large northern pike were captured and released which had the caudal process of white suckers protruding from their esophagus.

<u>Yellow Perch.</u> Yellow perch were collected in all habitats and comprised 13.7% of gill net, 5.3% of trawl nad 12.3% of trap net collections. Overall yellow perch were the fifth most abundant species collected.

Gill netting captured 15 yellow perch during winter and 14 of these were taken in shallow water. Most yellow perch (13) were taken at course 7 during winter. These differences in distribution were statistically significant. During summer and fall, differences in gill net catches were not significant. Similarly, little difference in trawl catches of yellow perch were observed between depths.

Yellow perch from gill nets ranged from 87-339 mm total length. Females were more abundant than males, particularly in winter when no males were taken. Yellow perch collected with bottom trawls ranged from 3[illegible] 291 mm total length and were predominantly immature fish. Except for one adult (176 mm), all yellow perch collected in the near-shore area with trap nets were immature (35-76 mm) and were most likely comprised of age 0-1 fish.

Daily migrations of yellow perch onshore at night and offshore during day have been reported (Engel and Magnusun, 1976) and are likely the reason gill net collections showed little difference in catch among depths for adult fish. Juvenile yellow perch appeared to be most abundant in the shore area, but they also utilized deeper water. In Lake Erie and Saginaw Bay (Lake Huron), juvenile yellow perch have been reported to move

offshore in summer and fall (Wells, 1968). Yellow perch have been reported to be day active or crepuscular (Ney, 1978). Larger trap net catches during day sets appear to confirm this behavior in the St. Marys River.

Analysis of yellow perch stomachs indicates mayfly nymphs are an important food item during winter. However, low numbers of yellow perch were taken during this period. During summer and fall, the yellow perch diet was quite variable. Insects and crustaceans comprised most of the food items numerically, while fish were also important volumetrically. Generally, smaller yellow perch fed on cladocera and smaller prey. Larger yellow perch took more insects and occasional fish. Food habits determined are in agreement with those reported previously from similar habitats (Ney, 1978).

Yellow perch appear to congregate in shallow water during winter where they feed predominantly on insect larvae. During open water periods yellow perch utilize all habitats and feed on a variety of organisms.

Brown Bullhead. Greatest numbers of brown bullheads were collected with trap nets set in emergent vegetation alongshore. These fish were primarily juveniles less than 90 mm total length and were likely young-of-the-year (Carlander, 1969). Adult bullhead also were captured in this habitat. Gill netting produced 25 brown bullheads which were mostly adult fish greater than 250 mm.

Segregation among age classes of centrarchids has been documented as a method of reducing interspecific competition (Mittlebach, 1980; Werner and Hall, 1977). Brown bullheads also may segregate for this reason.

Young-of-the-year brown bullhead may also remain in this habitat to avoid predation (Scott and Crossman, 1973) or because water temperatures are more favorable (Crawshaw, 1975).

Peaks in the length frequency distribution of brown bullhead at 50, 190, 270 and 330 mm suggest at least four age classes exist in the St. Marys River. In addition to the Lake Nicolet shoreline, immature brown bullhead are also abundant in Mirre Bay. Since similar habitat occurs throughout the St. Marys River recruitment should be high and gill net catches may not reflect actual abundance.

Trout-perch. Trout-perch were captured in all sampling gear and were particularly abundant in trawls comprising 20.0% of trawl collections. Considering all fish collected, trout-perch were the most abundant species. Seven hundred sixty-two individuals were taken which comprised 12.7% of all fish.

Greatest abundance occurred in Lake Munuscong during summer. At this station, 559 trout-perch were collected during summer: 415 in deep water and 144 in shallow water. Summer trawls at course 7 produced similar catches in shallow and deep water. During fall, catches of trout-perch were less at all sites, but remained most abundant in Lake Munuscong.

Trout-perch are considered a basic component of a percid community by Ryder and Kerr (1978) and are considered to be preferential food of walleye (Magnuson and Smith, 1963; Ryder and Kerr, 1978). Thus, distribution of trout-perch may well influence distribution of walleye. Magnuson and Smith (1963) report an extending spawning period for trout-perch commencing in May and continuing through August. Behavior during spawning involves moving to shoreline areas between 7:00 pm and midnight. Analysis of trawl and shoreline seine data suggest a similar behavior in the St. Marys

River. More than 42% of the trout-perch collected in trawls (1.6-3.1 m depth) were immature while less than 8% of trout-perch collected in shoreline seines were immature.

Trout-perch collected in trawls ranged from 23-114 mm total length. Females averaged 71.9 mm during summer and 59.7 mm during fall. Males averaged 71.8 and 53.5 mm during summer and fall respectively. Comparison of length frequency data with published data (Magnuson and Smith, 1963; Carlander, 1969) suggests that the majority of mature trout-perch captured were age I or II, while most of the immature trout-perch are young-of-the-year.

Spottail Shiner. Spotttail shiners were the third most abundant species collected by all methods combined. Most were collected during summer in trawls. A few spottail shiners were collected with gill nets during all seasons and occasional schools were collected with seines or trap nets.

During summer, trawl collections in deep water at both stations captured approximately three times as many spottail shiners as were collected in shallow water. Abundance in fall trawl samples was similar at all sites.

Spottail shiners have also been reported to be abundant in other portions of the Great Lakes (Brazo and Liston, 1979; Jude et al., 1975). Wells and McLain (1973) suggest the spottail shiner has ecologically replaced the emerald shiner in Lake Michigan.

Female spottail shiners were more abundant than males during summer and averaged (78 mm), slightly larger than males (70 mm). During fall, the reverse was true with both males (48 mm) and females (44 mm) averaging

smaller total length. Spottail shiners ranged from 22 to 108 mm total length with modes in distribution around 35, 60 and 85 mm. Comparison with data summarized in Carlander (1969) suggests the St. Marys River population is probably comprised of age 0, I and II fish.

Spottail shiners have been suggested to be an important forage base for piscivorous fish such as walleye and northern pike (Scott and Crossman, 1973). However, none of the fish stomachs examined in this study contained spottail shiners. Certain fishes did contain a high proportion of unidentifiable fish, some of which could have been spottail shiners. Underutilization of this species as forage has also been reported from Lake Michigan (Brazo and Liston, 1979).

Johnny Darter. Johnny darters were the second most abundant species collected by all sampling methods combined. Excepting a few individuals captured in shoreline seines and trap nets, johnny darters were taken by trawling.

Johnny darters were captured in approximately equal numbers during both summer and fall and exhibited a definite affinity for deeper water. The catch ratios of deep versus shallow water sites during summer and fall were 3.34:1 and 3.35:1 respectively. Previous investigators have observed low numbers of darters at depths less than 3 m and greater than 14 m, with greatest abundance in 3-10 m of water (Brazo and Liston, 1979; Wells, 1968).

Total length of johnny darters ranged from 22 to 60 mm. Females averaged larger than males during summer, but smaller during fall. Peaks in length frequency data were noted at the 25 and 50 mm intervals indicating two year classes. Brazo and Liston (1979) found few johnny darters older than II in fish ranging from 15-79 mm.

Johnny darters were identified in the stomachs of northern pike and yellow perch collected in the St. Marys River. Feeding on johnny darters by yellow perch (Brazo, 1973; Hauer, 1975) and burbot (Bohr, 1977) has been documented. Johnny darters are likely an important species in transforming energy from lower trophic levels to higher levels in the St. Marys River due to their abundance, benthic food habits (Bohr, 1980) and prey status.

Mottled Sculpin. Mottled sculpin were common in trawl samples from navigation course 7. Low numbers were also captured in trawls in Lake Munuscong and in trap nets at both stations.

Total length of mottled sculpin ranged from 22-89 mm. Females averaged larger than males during summer and smaller during fall. Catches were comprised mostly of 22-35 mm fish which were probably young-of-the-year and 36 to 55 mm fish.

Sculpins are suggested to be typical components of percid communities by Ryder and Kerr (1978). Although these authors do not list sculpins as a preferential food item, we found *Cottus* sp. in walleye, as well as northern pike and yellow perch stomachs. Like the johnny darter, mottled sculpins as well as slimy sculpins are likely important as links in energy transfer in the St. Marys River because of their invertebrate diet (Bohr, 1980) and status as prey.

Walleye. Walleye comprised 9.3% of the winter gill net catch, but were not common during other seasons or in other gear. A total of 64 walleye were collected during 1980. Due to the economic importance of this species, a brief discussion is included.

Forty-six walleye captured in gill nets ranged from 220 - 628 mm total length. During winter, most walleye were taken at the deep water

site in Lake Munuscong. Most of the fish collected during winter were mature. Summer and fall gill net data indicated a preference for shallow water, though this may be an artifact of sampling method. Summer and fall gill nets were fished only during low light periods (from evening until shortly after sunrise). Walleye display crepuscular or nocturnal movement (Ney, 1978) and are restricted to areas of low light intensity during the day and move alongshore in the evening (Kitchel et al., 1977).

In addition to gill net collections, 9 walleye were collected in trawls (130 - 478 mm TL) and 9 were collected during shoreline seining (66 - 203 mm). Most walleye collected by these methods were immature.

Walleye stomachs examined from individuals collected during winter contained little food. Eight of 13 stomachs were empty, one stomach contained a single fish and four stomachs contained 1 - 2 leeches. Stomachs examined during open water periods contained a predominance of fish in both immature and mature walleye, with various invertebrates also taken.

The diet of walleye in the St. Marys River during open water periods is similar to previous data reviewed by Ryder and Kerr (1978). However, no previous investigations of winter food habits were available. Kelso (1973) examined food habits of walleye from May through October and found that stomachs in October contained the least amount of food, but one of the highest caloric values of the season. Data presented in this paper also indicate that Hirudinea (leeches) had higher caloric values than fish eaten by the walleye (Kelso, 1973). As leeches are not abundant in the St. Marys River (Liston et al., 1980, Poe et al., 1979) walleye may selectively feed on them during winter to maximize caloric intake and minimize energy expenditures.

The Middle Neebish Channel of the St. Marys River does not appear to support large numbers of walleye. The walleye population(s) in this poriton of the St. Marys River are likely centered around the western 2/3 of Lake Munuscong. A substantial walleye fishery exists in this area and past trap net and gill net catches indicate greater walleye abundance west of the Rocky Point area (Michigan Department of Natural Resources, 1976).

SUMMARY

Juvenile and adult fish were sampled in nearshore and offshore habitats (adjacent shipping channels) at stations in navigation courses 5, 7, 9 and 10 of the St. Marys River. Sampling was concentrated in courses 7 and 9, where dredging activities are proposed. Field work was conducted during February and March, then again during June through November, 1980. Sampling gear included bottom gill nets during winter, and bottom gill nets, bottom trawls, trap nets, and shore seines during summer and fall. These studies were done to supplement the 1979 fish data by providing more winter observations, and more comparisons between the shallow and deep water fish fauna.

Bottom Gill Nets

Bottom gill nets consisted of 15.2 x 1.8 m (50' x 6') panels of 25 (1"), 51 (2"), 63 (2½"), 76 (3"), 102 (4"), 114 (4½") and 178 mm (7") stretched mesh nylon with No. 69 twine size (total net length was 106.4 m, or 350'). During winter, 40 gill net sets (20 nearshore, 20 offshore) collected 140 fish (catch per effort = 3.5 fish) of 11 species. Gill nets were set for 24 hours. Cisco comprised 40% of the catch. Other important species included northern pike (14.3%), white sucker (14.3%), yellow perch (10.7%) and walleye (9.3%). Considering all species and sampling areas, nearshore winter catches comprised 55% while offshore catches comprised 45% of the total number of fish. Cisco and white sucker were distributed evenly between

shallow and deep zones, yellow perch and northern pike favored shallow water, and walleye preferred deep water. These trends were not always consistent between navigation courses, however.

During summer, 14 gill net sets (12 hour sets) collected 492 fish (catch per effort = 35.1 fish) of 19 species. White sucker comprised 25.2% of the catch. Other important species included cisco (18.9%), yellow perch (16.1%), northern pike (6.9%), rock bass (5.3%), alewife (5.3%), walleye (4.3%), spottail shiner (4.2%), and brown bullhead (4.1%). Considering all species and sampling areas, nearshore summer catches comprised 61.8% while offshore catches comprised 38.2% of the total number of fish. Of the nine major species, six preferred nearshore water. Northern pike were concentrated offshore, while yellow perch and brown bullhead were more evenly distributed among depth zones. These trends were not always consistent, however, when navigation courses were examined separately.

During fall, 18 gill net sets (12 hour sets) collected 356 fish (catch per effort = 19.8 fish) of 16 species. Cisco comprised 33.4% of the catch. Other important species included white sucker (20.5%), rock bass (14.3%), yellow perch (11.5%) and northern pike (10.7%). Considering all species and sampling areas, nearshore fall catches comprised 48.9% while offshore catches comprised 51.1% of the total number of fish. Cisco and white sucker preferred nearshore water while rock bass and yellow perch were concentrated in deeper offshore waters. Northern pike did not exhibit a depth preference.

Bottom Trawls

Bottom trawl samples were collected at night with a semi-balloon otter trawl having a 4.9 m (16') head rope, 38 mm (1.5") stretched mesh body, and 3 mm (.1") bar mesh cod end liner. Each sample was a 5-minute tow.

Samples were collected nearshore (1.5 m; 5') and offshore (3.1 m; 10') at sites within navigation courses 7 and 9.

During summer, 2302 fish of 21 species were collected with 8 trawls (catch per effort = 287.8 fish). Trout-perch were most abundant comprising 27.4% of the total catch. Other important species included spottail shiner (18.7%), johnny darter (14.5%), mottled sculpin (9.6%), yellow perch (7.0%), white sucker (6.6%), and mimic shiner (4.8%). Comparisons were made between onshore and offshore data for navigation course 7. Offshore samples contained 58.6% while onshore samples contained 41.4% of all fish. Species preferring onshore water included spottail shiner, yellow perch, mimic shiner, logperch, and emerald shiner. Species preferring offshore water included johnny darter, mottled sculpin, brook stickleback, ninespine stickleback, and northern pike.

During fall, 1170 fish of 18 species were collected with 8 trawls (catch per effort = 146.3 fish). Johnny darter was dominant and comprised 31.6% of the catch. Other major species included mimic shiner (15.6%), rainbow smelt (11.2%), spottail shiner (8.7%), slimy sculpin (7.5%), mottled sculpin (6.7%), and trout-perch (5.6%). Comparisons were made between nearshore and offshore data for navigation course 7. Offshore samples contained 44.2% while nearshore samples contained 55.8% of all fish. Species caught mainly onshore were johnny darter, logperch, blacknose shiner, sand shiner, and walleye. Species associated mainly with deeper offshore water included brook stickleback, ninespine stickleback, northern pike, and mimic shiner.

Trap Nets

Trap nets were constructed with 6.35 mm (.25") bar mesh nylon webbing. Each net had a 15.2 x 1 m (50 x 3.3') lead, 2.2 x 1 m (7.2 x 3.3') wings,

a 1 m^2 (10.8 ft^2) pot and a single heart. A sample consisted of setting the gear for either the entire light or dark period of a day. Samples were taken nearshore in emergent vegetation and in open water in navigation courses 5, 7, and 9 during August, September, and October.

A total of 1251 fish of 26 species were taken with 16 trap net samples (catch per effort = 78.2 fish). Overall, brown bullhead was the most abundant (19.9% of total catch). Other major species included sand shiner (15.5%), bluegill (13.5%), yellow perch (12.3%), white sucker (10.4%) and blacknose shiner (10.5%). However, fish species composition differed between stations. Minnows (Cyprinidae) dominated collections from navigation course 7, while the bluegill comprised over half (54.6%) of fish from trap nets set in navigation course 9. In navigation course 5 (Lake Nicolet), habitats containing heavy cover, medium cover, and little cover (open water, no emergent macrophytes) were compared. Brown bullhead dominated samples from heavy cover, bluegill were dominant in medium cover, and yellow perch were most abundant in open areas.

Day and night comparisons revealed that about two-thirds of the fish were taken at night.

Shoreline Seine

Five seine samples were taken at night with a 61 x 1.8 m (200 x 6') bag seine having 6.35 mm (.25") bar mesh nylon. Shoreline hauls were made during July and October at sites along navigation courses 5, 7, and 9. A total of 309 fish (catch per effort = 61.8 fish) representing 20 species were taken. Spottail shiner comprised 54.8% of all individuals taken in July, while emerald shiner and trout-perch comprised 54.3% and 26.4% of October collections respectively.

General

In addition to catch data, new baseline data on length frequencies and sex composition of the following eight species are presented in the text: cisco, northern pike, white sucker, yellow perch, brown bullhead, trout-perch, spottail shiner, and johnny darter. Also, baseline data on food habits during winter and open water periods for cisco, northern pike, walleye, and yellow perch are detailed.

PHYSICAL AND CHEMICAL ASPECTS OF WATER

METHODS AND MATERIALS

Physical and chemical parameters measured conjunction with biological sampling in channel course 7 and Lake Munuscong included depth, water temperature, dissolved oxygen and turbidity. Methods used in the collection of these data were consistent with methods described in "Standard Methods for the Examination of Water and Wastewater" (APHA, 1971).

Depth was recorded each time a sample measurement was made. Water temperature was measured at mid-depth with a YSI thermister and telethermometer (Yellow Springs Instrument Co., Yellow Springs, Ohio). Dissolved oxygen was measured at mid-depth with YSI Model 54 dissolved oxygen meter. Turbidity samples were collected from 0.5 m below surface and analyzed with a Hach Model 2100A turbidimeter (Hach Chemical Co., Ames, Iowa). In addition to the above parameters, alkalinity and pH measurements (IL Model 175 pH meter, Instrumentation Laboratories, Boston, Mass.) were made on several sampling dates.

RESULTS

Water Temperature

Water temperatures recorded during sampling in February and March ranged from 0.1 to 1.0 C. Water temperatures during 11 - 25 February were 0.3 - 1.0 C. However, a severe cold weather period with daily low air temperatures of -21 to -29 F existed from 25 February through 1 March. This reduced water temperatures to 0.1 - 0.2 C at all

sampling sites. These water temperatures persisted until winter sampling was terminated on 5 March.

When sampling resumed in mid-April, water temperatures alongshore were approximately 2.0 C. However, temperatures in the shallow nearshore water varied considerably during spring (Table 1). As expected, water temperatures in the shallow depths warmed more rapidly and cooled earlier in the fall than temperatures offshore. Maximum water temperatures for all depth zones were recorded during late July through mid-August (Table 1).

Turbidity

Turbidity measurements ranged from 1.0 to 13.2 NTU during June through November, 1980 (Table 2). Seasonally, turbidity measurements were lowest in November and highest in September. Seventy-one percent of all turbidity measurements were 3.0 NTU or less. During June through November turbidity measurements at the nearshore sites averaged 3.0 NTU while the mean offshore turbidity was 2.4 NTU.

Dissolved Oxygen

Dissolved oxygen measurements ranged from 5.2 ppm to 12.2 ppm during April through October, 1980 (Table 3). Monthly mean dissolved oxygen measurements were fairly consistent. Greatest variation was noted during May and August (Table 3).

Other Chemical Parameters

In addition to the above parameters alkalinity and pH were recorded, but less frequently. Alkalinity was measured on 14 July, 11 September and 6 October. Alkalinity measured on these dates ranged from 46.0 - 78.0 ppm $CaCO_3$ (n = 5). All alkalinity was present as bicarbonate.

Table 1. Weekly ranges in water temperature measurements recorded in the St. Marys River at three depth intervals during 1980.

	Date	0.3 - 1.0 m	1.0 - 2.0 m	3.0 - 6.0 m
April	13-19	1.9 - 9.5		
	20-26			
	27-3			
May	3-10	15.0 - 18.0		
	11-17	9.5 - 13.5	6.8	
	18-24	14.5 - 21.5		
	25-31		7.0 - 9.5	
June	1-7	12.0 - 14.0	8.0 - 8.2	
	8-14	10.0 - 14.0	10.8	
	15-21			
	22-28	18.0 - 18.1	13.0 - 15.2	12.5
	29-5	12.0 - 15.8	12.6 - 14.0	12.5 - 12.8
July	6-12	19.9 - 20.3	17.4 - 17.9	
	13-19		17.5	17.0 - 18.8
	20-26	20.2 - 21.0	18.0 - 19.4	18.0
	27-2	23.0 - 24.2	20.1	
August	3-9		24.5	
	10-16	18.0 - 20.9	18.0 - 19.9	18.0
	17-23	19.0 - 19.4	19.2 - 19.9	18.5
	24-30		17.0 - 18.5	16.0 - 16.5
	31-6	19.8 - 20.4	18.2 - 18.3	
September	7-13		17.0 - 20.5	16.0 - 16.5
	14-20		14.0	
	21-27	7.0	11.0 - 12.0	12.0
	28-4		10.9 - 11.0	11.8
October	5-11		9.5	7.0 - 9.1
	12-18	5.9 - 7.3	8.1 - 8.1	7.0 - 7.8
	19-25		5.2 - 6.8	6.0 - 7.6
	26-1	4.0	4.5	4.3 - 5.0
November	2-8		2.9 - 4.0	4.0
	9-15		2.5 - 2.7	2.4 - 2.7
	16-22		2.1 - 3.1	3.1 - 3.2

Table 2. Monthly descriptive statistics for turbidity measurements taken in the Middle Neebish Channel, St. Marys River, from 23 June through 17 November, 1980. Units are NTU's.

Month	n	$\bar{x}$	s	range
June	2	2.6	0.1	2.5 - 2.7
July	6	2.6	0.6	1.8 - 3.2
August	7	2.7	0.4	1.6 - 2.8
September	8	4.9	3.4	3.0 - 13.3
October	10	2.3	0.8	1.3 - 3.7
November	8	1.8	0.8	1.0 - 3.0

Table 3. Monthly descriptive statistics for dissolved oxygen measurements taken in the St. Marys River from 12 April through 16 October 1980.

Month	n	$\bar{x}$	Range
April	1	9.0	
May	8	10.6	7.0 - 12.2
June	12	10.5	9.2 - 11.8
July	13	10.5	9.2 - 11.8
August	18	10.3	5.2 - 12.0
September	14	11.0	9.3 - 12.1
October	2	10.4	10.2 - 10.7

Fifteen pH measurements recorded from 14 July through 11 September ranged from 6.9 to 7.6 standard units. The greatest difference in 7 nearshore - offshore comparisons was 0.2 standard units.

DISCUSSION

Water Temperature

Water temperature may be the most influential environmental factor to aquatic animals. The rates of many biological processes increase with increasing temperature largely because rates of chemical reactions are temperature dependent (Warren, 1971).

Water temperatures along the shoreline were much warmer than offshore waters in spring and early summer. While offshore water temperatures in the St. Marys River are influenced mainly by Lake Superior (Liston et al., 1980), nearshore water temperatures appear to be controlled as much by solar radiation and atmospheric conditions.

Maximum water temperatures were recorded from late July through early August coinciding with the period of maximum solar radiation (Hutchinson, 1957). Water temperature began to decline in August and continued to do so through November.

Dissolved Oxygen

Dissolved oxygen measurements ranged from 5.2 - 12.2 ppm during 1980. This is similar to the range recorded during 1979 (Liston et al., 1980) and similar to measurements recorded from Lake Nicolet by Kenaga (1979).

Dissolved oxygen measurements below 7.6 ppm were all recorded at the nearshore area. These measurements were taken when sampling for ichthyoplankton at night, the time when lowest dissolved oxygen levels may be expected due to respiration (Hutchinson, 1957). Organic

material which collected among emergent vegetation may have influenced dissolved oxygen through decomposition on several occasions, although no odor was noted in these areas.

Turbidity

The range in turbidity readings recorded offshore (1.1 - 3.5 NTU) was less than the range in readings recorded nearshore (1.0 - 13.2 NTU) during 1980. Offshore turbidity values were similar to 1979 measurements (Liston et al., 1980). Nearshore turbidity values were lower in 1980 than those measured on several occasions during 1979 (Liston et al., 1980). However, turbidity was not routinely measured at nearshore sites prior to 1980.

Greatest turbidity values were recorded during September. September was characterized by strong winds which no doubt created turbulence resuspending fine particles in nearshore areas. Lowest turbidity values were recorded during November.

Other Chemical Parameters

Alkalinity and pH values recorded during 1980 were similar to values recorded during 1979 (Liston et al., 1980). No variation in nearshore versus offshore alkalinity values was found. The maximum range in pH among offshore and nearshore sites was 0.2 standard units.

Alkalinity values were generally low (46.0 - 78.0 ppm) and were similar to values reported by previous workers from the St. Marys River (Kenaga, 1979). Similar pH values were also reported from the St. Marys River by Kenaga (1979) and all pH values (6.9 - 7.6 S.U.) were within the range described for natural waters (Wetzel, 1975).

SUMMARY

Physical-chemical aspects of waters in navigation courses 7, 9, and 10 of the Middle Neebish Channel, St. Marys River, were determined at nearshore (0.3 - 2.0 m; 1 - 6.6') and deep (3 - 6 m; 9.8 - 19.7') sites during February to November 1980, to expand the baseline data at proposed dredging sites. Most measurements were taken in conjunction with biological sampling.

Water temperatures ranged from 0.1 - 1.0 C during February and March. Beginning in mid-April, temperatures were approximately 2.0 C. Maximum temperatures occurred during late July and mid-August, with values as great as 18.8 C (deep water) and 24.5 C (shallow water) recorded. Temperatures had dropped to 2.1 - 3.2 C by late November. Shallow waters warmed more rapidly in spring and cooled earlier in the fall than deeper water.

Turbidity ranged from 1.0 - 13.2 NTU during June through November, though most measurements (71%) were 3.0 NTU or less. Highest turbidities occurred nearshore, and turbidity averaged 3.0 NTU nearshore compared to 2.4 NTU offshore.

Dissolved oxygen ranged from 5.2 ppm to 12.2 ppm during April through October. All values less than 7.6 ppm were from nearshore waters. Lowest values occurred during night sampling near beds of emergent vegetation.

Alkalinity and pH were determined less frequently than other physical-chemical measurements in 1980. Alkalinity measurements taken on 14 July, 11 September, and 6 October ranged from 46.0 - 78.0 ppm $CaCO_3$. Fifteen pH measurements taken during 14 July through 11 September ranged from 6.9 to 7.6 standard units. No consistent differences between nearshore and offshore values for pH and alkalinity were apparent.

LITERATURE CITED

American Public Health Association. 1971. Standard Methods for the Examination of Water and Wastewater, 13th ed. APHA, New York. 874 pp.

Amundrud, J. R., D. J. Faber, and A. Keast. 1974. Seasonal succession of free-swimming perciform larvae in Lake Opinicon, Ontario. J. Fish. Res. Bd. Canada. 31: 1661-1665.

Balon, E. K. 1975. Reproductive guilds of fishes: a proposal and definition. J. Fish. Res. Bd. Canada. 32: 821-864.

Beamish, R. J. 1972. Design of a trapnet for sampling shallow-water habitats. Fish. Res. Bd. Canada Tech. Rep. 305. 15 pp.

Behmer, D. J., G. R. Gleason, and T. Gorenflo. 1980. Identification and evaluation of lake whitefish and herring spawning grounds in the St. Marys River Area. U. S. Corps of Engineers, Contract Number DACW35-80-M-0193. 29 pp.

Birge, E. A., and C. Juday. 1929. Transmission of solar radiation by the waters of inland lakes. Trans. Wisc. Acad. Sci. Arts Lett. 24: 509-580.

Bohr, J. R. 1977. Food habits of the burbot (Lota lota) in the Ludington Pumped Storage Reservoir at Ludington Michigan. Mich. State Univ., Dept. Fish. Wildl. Unpub. Rep.

Bohr, J. R. 1980. Abundance, distribution and community interactions of demersal fishes inhabiting a new pumped storage reservoir on Lake Michigan near Ludington, Michigan. M. S. Thesis, Mich. State Univ. 62 pp.

Bousfield, E. L. 1958. Freshwater amphipod crustaceans of glaciated North America. Can. Field - Nat. 72: 55-113.

Braum, E. 1967. The survival of fish larvae in reference to their feeding behavior and the food supply, pp. 113-131. In Gerking, S. D. (ed.). The biological basis of freshwater fish production. Blackwell, Oxford and Edinburgh.

Brazo, D. C. 1973. Fecundity, food habits and certain allometric features of the yellow perch (Perca flavescens Mitchill) before operation of a pumped storage plant on Lake Michigan. M. S. Thesis, Mich. State Univ. 75 pp.

Brazo, D. C., and C. R. Liston. 1979. The effects of five years of operation of the Ludington Pumped Storage Power Plant on the fishery resources of Lake Michigan (1972-77), Mich. State Univ., Dept. Fish. Wildl., 1977 Ann. Rep. to Consumers Power Co., Vol. II, No. 1 (Fish. Research). 406 pp.

Carlander, K. D. 1953. Use of gill nets in studying fish populations, Clear Lake, Iowa. Proc. Iowa Acad. Sci. 60: 621-625.

Carlander, K. D. 1969. Handbook of freshwater fishery biology. Vol. I. Life history data on freshwater fishes of the United States and Canada, exclusive of the Perciformes. Iowa State Univ. Press, Ames, Iowa. 752 pp.

Clady, M. D. 1976. Distribution and abundance of larval ciscoes, Coregonus artedii, and burbot, Lota lota, in Oneida Lake. J. Great Lakes Res. 2(2): 234-247.

Colby, R. J., and L. T. Brooke. 1969. Cisco (Coregonus artedii) mortalities in a southern Michigan Lake, July 1968. Limnol. Oceanogr. 14: 958-960.

Cooper, J. E. 1978a. Identification of eggs, larvae, and juveniles of rainbow smelt, Osmerus mordax, with comparisons to larval alewife, Alosa pseudoharengus, and gizzard shad, Dorosoma cepedianum. Trans. Am. Fish. Soc. 107(1): 56-62.

Cooper, J. E. 1978b. Eggs and larvae of the logperch, Percina caprodes (Rafinesque). Am. Midl. Nat. 99(2): 257-269.

Crawshaw, L. I. 1975. Attainment of final thermal preferendum in brown bullheads acclimated to different temperatures. Comp. Biochem. Physiol. 52(1): 171-173.

Delorme, L. D. 1978. Distribution of freshwater ostracods in Lake Erie. J. Great Lakes Res. 4: 216-220.

Dermott, R. 1978. Benthic diversity and substrate-fauna associations in Lake Superior. J. Great Lakes Res. 4: 505-512.

Diana, J. S. 1979. The feeding pattern and daily ration of a top carnivore, the northern pike (Esox lucius). Can. J. Zool. 57: 2121-2127.

Diana, J. S., and W. C. Mackay. 1979. Timing and magnitude of energy deposition and loss in the body, liver, and gonads of northern pike (Esox lucius). J. Fish. Res. Bd. Canada. 36: 481-487.

Diana, J. S., W. C. Mackay, and M. Ehrman. 1977. Movements and habitat preference of northern pike (Esox lucius) in Lac Ste. Anne, Alberta. Trans. Am. Fish. Soc. 106: 560-565.

Dorr, J. A. III, D. J. Jude, F. J. Tesar and N. J. Thurber. 1976. Identification of larval fishes taken from inshore waters of southeastern Lake Michigan near the Donald C. Cook Nuclear Plant, 1973-1975, pp. 61-82. In J. Boreman (ed.), Great Lakes Fish Egg and Larvae Identification: Proceedings of a Workshop. U.S. Fish and Wildlife Service. FWS/OBS-76-23.

Dryer, W. R., and J. Biel. 1964. Life history of lake herring in Lake Superior. Fish. Bull. 63(3): 493-530.

Duffy, W. G. and C. R. Liston. 1978. An analysis of the percentage composition and abundance of benthic macroinvertebrates in Lake Michigan and adjacent to the Ludington Pumped Storage Plant, 1972-1976. Mich. State Univ., Dept. Fish. Wildl., 1976 Ann. Rep. to Consumers Power Co., Vol. II, No. 1 (Limnol. Research). 97 pp.

Duncan, T. O. 1978. Collection bucket for use with tow nets for larval fish. Prog. Fish-Cult. 40(3): 118-119.

Edmunds, G. F., S. L. Henson, and N. L. Berner. 1976. The Mayflies of North and Central America. Univ. Minn. Press, Minneapolis. 330 pp.

Edsall, T. A., and P. J. Colby. 1970. Temperature tolerance of young-of-the-year cisco, Coregonus artedii. Trans Am. Fish. Soc. 99 (3): 526-531.

Elliott, J. M. 1977. Some Methods for the Statistical Analysis of Samples of Benthic Invertebrates, 2nd ed. Freshwater Biol. Assoc. Pub. No. 25. 156 pp.

Engle, S. 1976. Food habits and prey selection of coho salmon (Oncorhynchus kisutch) and cisco (Coregonus artedii) in relation to zooplankton dynamics in Pallette Lake, Wisconsin. Trans. Amer. Fish. Soc. 105(5): 607-614.

Engle, S., and J. J. Magnuson. 1976. Vertical and horizontal distributions of coho salmon (Oncorhynchus kisutch), yellow perch (Perca flavescens), and cisco (Coregonus artedii) in Pallette Lake, Wisconsin. J. Fish. Res. Bd. Canada. 33(12): 2710-2719.

Faber, D. 1967. Limnetic larval fish in northern Wisconsin lakes. J. Fish. Res. Bd. Canada. 24: 927-937.

Faber, D. 1970. Ecological observations on newly hatched lake whitefish in South Bay, Lake Huron, pp. 481-500. In C. C. Lindsey and C. S. Woods (eds.), Biology of Coregonid Fishes. Univ. of Manitoba Press, Winnipeg.

Fassett, N. C. 1957. A Manual of Aquatic Plants. Second Edition. University of Wisconsin Press, Madison, Wisconsin. 405 pp.

Fish, M. P. 1932. Contributions to the early life histories of fish from Lake Erie and its tributary waters. U.S. Bur. Fish., Bull. 47: 293-398.

Galloway, J. E. and N. R. Kevern. 1976. Michigan Suckers: Their Life Histories, Abundance, and Potential for Harvest. Tech. Rept. No. 53, MICH-SG-206, Mich. Sea Grant Prog., Ann Arbor, Mich. 46 pp.

Gerrish, N., and J. M. Bristow. 1979. Macroinvertebrate associations with aquatic macrophytes and artificial substrates. J. Great Lakes Res. 5(1): 69-72.

Gleason, G. R., D. J. Behmer and K. L. Vincent. 1979. Evaluation of benthic dislocation due to pressure waves initiated by vessel passage in the St. Marys River. Dep. Biol. Chem., Lake Superior St. Coll., Sault Ste. Marie, Michigan. 23 pp. and appendices.

Graser, L. F. 1978. Flow-through collection bucket for larval fish. Prog. Fish-Cult. 40(2): 78-79.

Hauer, F. R. 1975. Comparison of preoperational and operational abundance, age, length-weight relationships, and food habits of yellow perch Perca flavescens (Mitchill), in Lake Michigan and the Ludington Pumped Storage Reservoir. M. S. Thesis, Mich. State Univ. 75 pp.

Heard, W. H., and J. B. Burch. 1966. Key to the genera of freshwater pelecypods (mussels and clams) of Michigan. University of Michigan, Museum of Zoology, Circular No. 4. 14 pp.

Heard, W. R. 1965. Limnetic cottid larvae and their utilization as food by juvenile sockeye salmon. Trans. Am. Fish. Soc. 94: 191-193.

Hilsenhoff, W. L. 1975. Aquatic insects of Wisconsin: With Generic Keys and Notes on Biology, Ecology, and Distribution. Tech. Bull. No. 89, Dept. Nat. Res., Madison, Wisconsin. 53 pp.

Hiltunen, J. K. 1978. Investigation of macrobenthos in the St. Marys River during an experiment to extend navigation through winter, 1974-1975. U.S. Fish and Wildl. Serv., Great Lakes Fish. Lab. 177 pp.

Hoagman, W. J. 1974. Vital activity parameters as related to the early life history of larval and postlarval lake whitefish (Coregonus clupeaformis), pp. 547-558. In J. H. S. Blaxter (ed.), The Early Life History of Fish. Research Laboratory of the Scottish Marine Biological Association at Oban, Scotland, May 17-23, 1973. Springer-Verlag, New York.

Hogue, J. J., R. Wallus, and L. K. Kay. 1976. Preliminary Guide to the Identification of Larval Fishes in the Tennessee River. TVA Technical Note B 19. December 1976. 66 pp.

Holsinger, J. R. 1976. The Freshwater Amphipod Crustaceans (Gammaridae) of North America. U.S. Environmental Protection Agency. 89 pp.

Houde, E. D. 1969. Distribution of larval walleye and yellow perch in a bay of Oneida Lake and its relation to water currents and zooplankton. N. Y. Fish and Game J. 16: 184-205.

Hutchinson, G. E. 1957. A Treatise on Limnology. Vol. I, Geography, Physics and Chemistry. John Wiley and Sons, N.Y. 1015 pp.

Janssens, J. 1978. Feeding-behavior repertoire of the alewife, Alosa pseudoharengus, and the ciscoes Coregonus hoyi and C. artedii. J. Fish Res. Bd. Canada. 35: 249-253.

Jude, D. J., F. J. Tesar, J. A. Door III, T. J. Miller, P. J. Rago, and D. J. Stewart. 1975. Inshore Lake Michigan Fish Populations Near the D. C. Cook Nuclear Power Plant, 1973. Great Lakes Res. Div., Univ. of Michigan, Spec. Rept. No. 52. 267 pp.

Kavaliers, M. 1980. Circadian activity of the white sucker, Catostomus commersoni; comparison of individual and shoaling fish. Can. J. Zool. 58: 1399-1403.

Keast, A. 1968. Feeding of some Great Lakes fishes at low temperatures. J. Fish. Res. Bd. Canada. 22: 1357-1377.

Keast, A. 1978. Trophic and spatial interrelationships in the fish species of an Ontario temperate lake. Env. Biol. Fish 3(1): 7-31.

Kelso, J. R. M. 1973. Seasonal energy changes in walleye and their diet in West Blue Lake, Manitoba. Trans. Amer. Fish. Soc. 102: 363-368.

Kelso, J. R. M. and J. K. Leslie. 1979. Entrainment of larval fish by Douglas Point generating station, Lake Huron, in relation to seasonal succession and distribution. J. Fish. Res. Bd. Canada. 36: 37-41.

Kelso, J. R. M. and F. J. Ward. 1977. Unexploited percid populations of West Blue Lake, Manitoba and their interactions. J. Fish. Res. Bd. Canada. 34: 1655-1669.

Kenaga, D. 1979. A biological and chemical survey of the St. Marys River in the vicinity of Sault Ste. Marie, June 19-20, 1978. Water Qual. Div., Mich. Dept. Nat. Res.

Kitchell, J. R., M. G. Johnson, C. K. Minns, K. H. Loftus, L. Grieg, and C. H. Oliver. 1977. Percid habitat: the river analogy. J. Fish. Res. Bd. Canada. 34: 1936-1940.

Lagler, K. F. 1968. Capture, sampling and examination of fishes. pp. 7-45. In W. E. Ricker (ed.), Methods for assessment of fish production in fresh water. IBP Handbook No. 3. Blackwell Scientific, Oxford. 313 pp.

Lam, C. N. H. and J. C. Roff. 1977. A method for separating alewife Alosa pseudoharengus from gizzard shad Dorosoma cepedianum larvae. J. Great. Lakes Res. 3(3-4): 313-316.

Lawrie, A. H. 1978. The fish community of Lake Superior. J. Great Lakes Res. 4: 513-549.

Lindstrom, T. 1970. Habitats of whitefish in some north Swedish lakes at different stages of life history, pp. 461-479. In C. C. Lindsey and C. S. Woods (eds.), Biology of Coregonid Fishes. Univ. of Manitoba Press, Winnipeg.

Lippson, A. J. and R. L. Moran. 1974. Manual for Identification of Early Developmental Stages of Fishes of Potomac River Estuaries. Marietta Corp. Spec. Publ. PPSP-MP-13. 282 pp.

Liston, C. R., W. G. Duffy, D. E. Ashton, C. D. McNabb, and F. E. Koehler. 1980. Environmental baseline and evaluation of the St. Marys River Dredging. Mich. State Univ., Dep. Fish. Wildl. Rep. to U.S. Fish Wildl. Service, FWS/OBS-80/62. 295 pp.

Long, W. L. and W. W. Ballard. 1976. Normal embryonic stages of the white sucker, Catostomus commersoni. Copeia 1976 (2): 342-351.

Magnuson, J. L. and L. L. Smith. 1963. Some phases of the life history of the trout-perch. Ecology 44(1): 85-95.

Mansueti, A. J. 1964. Early development of the yellow perch, Perca flavescens. Chesapeake Sci. 5(1-2): 46-66.

Mansueti, A. J. and J. D. Hardy. 1967. Development of Fishes of the Chesapeake Bay Region. An Atlas of Egg, Larval, and Juvenile Stages. Part 1. Univ. of Maryland, Baltimore. 202 pp.

Mason, W. T. 1973. An Introduction to the Identification of Chironomid Larvae. U.S. Environmental Protection Agency. 90 pp.

May, E. B. and C. R. Gasaway. 1967. A Preliminary Key to the Identification of Larval Fishes of Oklahoma, with Particular Reference to Canton Reservoir Including a Selected Bibliography. Oklahoma Fish. Res. Lab. Bull. No. 5. Norman, Oklahoma. 42 pp.

Meyer, F. A. 1970. Development of some larval centrarchids. Prog. Fish-Cult. 32(3): 130-136.

Michigan Department of Natural Resources. 1976. Marquette Great Lakes Unit Report. Munuscong Walleye Spawning Survey. St. Marys River. 1 p. mimeo.

Mittlebach, G. G. 1980. Foraging efficiency and size-class competition in the bluegill sunfish (Lepomis macrochirus). Ph.D. Thesis, Mich. State Univ., Dept. Zool. 103 pp.

Moen, T. and D. Henegar. 1971. Movement and recovery of tagged northern pike in Lake Oake, South and North Dakota, 1964-68. Pages 85-93. In G. E. Hall (ed.), Reservoir fisheries and limnology. Am. Fish. Soc. Spec. Publ. 8. Washington, D.C.

Morton, J. W. 1977. Ecological Effects of Dredging and Dredge Spoil Disposal: A Literature Review. U.S. Fish Wildl. Serv. Tech. Pap. 94. 33 pp.

Nelson, D. N. and R. A. Cole. 1975. The Distribution and Abundance of Larval Fishes Along the Western Shore of Lake Erie at Monroe, Michigan. Tech. Rept. No. 32.4, Inst. Water Res., Michigan State Univ., East Lansing, Mich. 66 pp.

Nelson, W. R. 1968. Embryo and larval characteristics of sauger, walleye and their reciprocal hybrids. Trans. Am. Fish. Soc. 97(2): 167-174.

Ney, J. J. 1978. A synoptic review of yellow perch and walleye biology. Am. Fish. Soc. Spec. Publ. 11: 1-12.

Norden, C. R. 1961. The identification of larval yellow perch, Perca flavescens, and walleye, Stizostedion vitreum. Copeia 1961(3): 282-288.

Norden, C. R. 1967. Development and identification of the larval alewife, Alosa pseudoharengus, (Wilson), in Lake Michigan. Proc. 10th Conference on Great Lakes Research: 70-78.

Peddicord, R. K., and V. A. McFarland. 1978. Effects of Suspended Dredged Material on Aquatic Animals. Dredged Material Research Program Tech. Rept. D-78-29. U.S. Army Corps. Eng. 115 pp.

Pennak, R. W. 1978. Freshwater Invertebrates of the United States, 2nd ed. John Wiley and Sons. New York. 803 pp.

Peo, T. P., T. A. Edsall, and J. K. Hiltunen. 1979. Effects of Ship-induced Waves in an Ice Environment on the St. Marys River Ecosystem. Rept. Project No. 5100 Great Lakes Basin Comm. 24 pp. and appendices.

Prescott, G. W. 1961. Algae of the Western Great Lakes Area. W. C. Brown Co., Dubuque, Iowa. 977 pp.

Ryder, R. A. and S. R. Kerr. 1978. The adult walleye in the percid community - a niche definition based on feeding behavior and food specificity. Am. Fish. Soc. Spec. Publ. 11: 39-51.

Scott, W. B., and E. J. Crossman. 1973. Freshwater Fishes of Canada. Fish. Res. Bd. Canada Bull. 184. 966 pp.

Sheldon, A. A. 1968. Drift, growth and mortality of juvenile sculpins in Sagehen Creek, California. Trans. Am. Fish. Soc. (7(4): 495-496.

Shenker, J. M. and J. M. Dean. 1979. The utilization of an intertidal salt marsh creek by larval and juvenile fishes: abundance, density and temporal variation. Estuaries 2(3):154-163.

Sinclair, D. C. 1968. Diel limnetic occurrence of young Cottus asper in two British Columbia lakes. J. Fish. Res. Bd. Canada. 25(9): 1997-2000.

Smitn, B. A. 1971. The Fishes of Four Low-salinity Tidal Tributaries of the Delaware River Estuary. Ichthyological Associates. Bull. No. 5. 291 pp.

Stern, E. M., and W. B. Stickle. 1978. Effects of Turbidity and Suspended Material in Aquatic Environments. Literature Review. Dredged Material Research Program Tech. Rept. D-78-21. 118 pp.

Stross, R. G. 1979. Density and boundary regulations of the Nitella meadow in Lake George, New York. Aquatic Bot. 6: 285-300.

Swanson, G. A., G. L. Krapu, and J. R. Serie. 1979. Foods of laying female dabbling ducks on the breeding grounds, pp. 47-57. In T. A. Bookout (ed.), Waterfowl and Wetlands - an integrated review. LaCrosse Printing Company, Inc., LaCross, Wisconsin. 147 pp.

Taber, C. 1969. The distribution and identification of larval fishes in the Buncombe Creek arm of Lake Texoma with observations on spawning hàbits and relative abundance. Ph.D. Thesis, Univ. of Oklahoma, Norman, Oklahoma. 120 pp.

Tarplee, W. H., W. T. Bryson, and R. G. Sherfinski. 1979. Portable push-net apparatus for sampling ichthyoplankton. Prog. Fish-Cult. 41(4):213-215.

Thomas, D. L. 1971. The Early Life History and Ecology of Six Species of Drum (Sciaenidae) in the Lower Delaware River, A Brackish Tidal Estuary. Ichthyological Associates, Bull. No. 3. 247 pp.

U.S. Fish and Wildlife Service, Lamprey Control Laboratory, Ludington, Michigan. Artificial key to the small larvae (under 40 mm) of 3 genera of lamprey inhabiting the streams of the Great Lakes. 2 pp. Unpublished.

Voss, E. G. 1972. Michigan Flora. I. Gymnosperms and Monocots. Cranbrook Institute of Science. Bloomfield Hills, Michigan. 488 pp.

Warren, C. E. 1971. Biology and Water Pollution Control. W. B. Saunders Co., Philadelphia. 434 pp.

Weber, C. I. 1971. A Guide to the Common Diatoms at Water Pollution Surveillance System Stations. U.S. Environmental Protection Agency. Cincinnati, Ohio. 98 pp.

Wells, L. 1968. Seasonal depth distribution of fish in southeastern Lake Michigan. U.S. Fish Wildlife Serv. Fish. Bull. 67: 1-15.

Wells, L., and A. L. McLain. 1973. Lake Michigan: Man's Effects on Native Fish Stocks and Other Biota. Great Lakes Fish Comm. Tech. Rept. No. 20. 55 pp.

Werner, E. E., and D. J. Hall. 1977. Habitat shift in two sunfishes (Centrarchidae). Ecology 58(4): 869-876.

Werner, E. E., D. J. Hall, and M. D. Werner. 1978. Littoral zone fish communities of two Florida lakes and a comparison with Michigan lakes. Env. Biol. Fish. 3(2): 163-172.

Wetzel, R. G. 1975. Limnology. W. B. Saunders, Philadelphia. 743 pp.

Wiggins, G. B. 1977. Larvae of the North American Caddisfly Genera (Trichoptera). Univ. of Toronto Press, Toronto. 401 pp.

Williams, W. D. 1976. Freshwater Isopods (Asellidae) of North America. USEPA. Biota of Freshwater Ecosystems Identification Manual No. 8. 45 pp.

Wood, R. D. 1967. Charophytes of North America. Stella's Printing. West Kingston, Rhode Island. 72 pp.

Wright, A. T., and R. Schorffaar. 1976. Summary of August, 1975, St. Marys River synoptic fish survey. Mich. Dept. Nat. Res., Fish. Div. 14 pp.